UNIVERSITY OF BRISTOL

THE ANNUAL REPORT

OF THE

Agricultural and Horticultural Research Station

(THE NATIONAL FRUIT AND CIDER INSTITUTE)

LONG ASHTON, BRISTOL

1953

BATH :
PRINTED BY THE MENDIP PRESS LTD.

Jubilee Celebrations. Emeritus Professor B. T. P. Barker plants a tree of Ashton Brown Jersey. July 23rd, 1953. (See p. 31).

AGRICULTURAL COMMITTEE, 1953-54

Appointed by the Ministry of Agriculture and Fisheries.

A. WOODALL, Esq., 2, Oak Bank, South Road, Weston-super-Mare.

Appointed by the National Fruit and Cider Institute.

CAPTAIN D. M. WILLS, C.B.E. (*Chairman*), Barley Wood, Wrington, Somerset.
C. P. NORBURY, Esq., Sherridge, near Malvern, Worcestershire.
T. N. HOBLYN, Esq., East Malling Research Station, near Maidstone, Kent.
E. BALL, Esq., Oldfield, Pipe and Lyde, Hereford.
GILES TUKER, Esq., Butts Green Orchards, Danbury, Essex.
M. B. CRANE, Esq., F.R.S., Firs Farm, Haughley, near Stowmarket, Suffolk.
T. W. BARNES, Esq., Showle Court, Yarkhill, Ledbury, Hereford.

Appointed by the Senate of the University of Bristol.

PROFESSOR T. WALLACE, C.B.E., M.C., D.Sc., V.M.H., F.R.S., Professor of Horticultural Chemistry in the University.
PROFESSOR MACGREGOR SKENE, D.Sc., Professor of Botany in the University.
PROFESSOR W. E. GARNER, C.B.E., D.Sc., F.R.S., Professor of Inorganic and Physical Chemistry in the University.
PROFESSOR FREDERICK BLAKEMORE, D.V.Sc., M.R.C.V.S., D.V.S.M., Professor of Veterinary Medicine in the University.

Appointed by the Council of the University of Bristol.

THE VICE-CHANCELLOR (SIR PHILIP MORRIS, C.B.E., M.A., LL.D.), The University, Bristol.
ANDREW HAGGARD, Esq., The Hilltop Fruit Farm, Ledbury, Herefordshire.
SIR ARTHUR HOBHOUSE, M.A., J.P., Hadspen House, Castle Cary, Somerset.
THE RIGHT HON. EARL WALDEGRAVE, Chewton Priory, Bath.
PROFESSOR J. L. M. MORRISON, D.Sc., Professor of Mechanical Engineering in the University.

Appointed by the Gloucestershire County Council.

JOSEPH H. ALPASS, Esq., C.B.E., Elberton, Ormerod Road, Stoke Bishop, Bristol 9.

Appointed by the Somerset County Council.

MAJOR W. F. Q. SHULDHAM, East Stoke House, Stoke-under-Ham, Somerset.

Appointed by the Wiltshire County Council.

O. M. PEALL, Esq., Hatfield Farm, Oare, Marlborough, Wiltshire.

Appointed by the Food Investigation Board.

(Vacant).

Appointed by the National Association of Cider Makers.

H. H. BULMER, Esq., Ryeland Street, Hereford.

Appointed by the Apple Juice Producers' Association of Great Britain.

V. L. S. CHARLEY, Esq., Ph.D., 40, Boxbush Road, Coleford, Glos.

Co-opted Members.

A. ESMOND ROBINSON, Esq., O.B.E., M.C., The Batch, Flax Bourton, Nr. Bristol.
C. E. HUDSON, Esq., Senior Education and Advisory Officer, Ministry of Agriculture and Fisheries, 1–4, Cambridge Terrace, London, N.W.1.

Secretary.

THE REGISTRAR AND SECRETARY OF THE UNIVERSITY.
H. C. BUTTERFIELD, M.A. (Com.).

LIST OF STAFF—1953.

Long Ashton Research Station.

Director :
PROFESSOR T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

Secretary :
A. L. LEGGETT, A.S.A.A.

Nutrition of Fruit Plants :
C. BOULD, M.Sc., Ph.D.
J. A. H. TOLHURST, B.Sc. (*Resigned* 28 *February*, 1953).
D. G. HILL-COTTINGHAM, M.Sc. (*Appointed* 10 *August*, 1953).
MISS B. HOOD.

Pomology and Plant Breeding :
L. C. LUCKWILL, B.Sc., Ph.D.
G. T. SPINKS, M.A., Dip. Agric. (Plant Breeding) (*Retired* 30 *September*, 1953).
E. W. HOBBIS, B.Sc., N.D.H. (Plantations Officer).
D. L. ABBOTT, B.Sc.
R. R. WILLIAMS, B.Sc., Dip. Hort.
MISS B. A. RAKE, B.Sc., N.D.H.
P. S. WEAVER.

Plant Physiology :
E. J. HEWITT, B.Sc., Ph.D., A.K.C. (*Seconded to A.R.C. Unit of Plant Nutrition*).

Chemistry of Insecticides and Fungicides :
J. T. MARTIN, B.Sc., Ph.D., D.Sc., F.R.I.C.
D. WOODCOCK, M.Sc., Ph.D., F.R.I.C. (Organic Chemistry).
W. D. E. THOMAS, B.Sc., Ph.D., A.R.I.C. (Physical Chemistry).
*E. SOMERS, M.Sc.
†G. V. COLES, B.Sc.
C. P. LLOYD-JONES, B.Sc., A.R.I.C.
R. F. BATT.
MRS. P. M. POPE (née James).
A. J. SIMS.
J. F. HARRIS.

Entomology :
H. G. H. KEARNS, B.Sc., Ph.D., Dip. Agric.
S. H. BENNETT, B.Sc.
N. G. MORGAN, B.Sc.
A. STRINGER, B.Sc., A.R.C.S.
A. H. WILKINS.
MRS. E. B. SALWAY (née Ward).
G. BRACEY.
MISS M. P. SCADDING.
J. H. RUSSELL.

Plant Pathology :
R. W. MARSH, M.A.
R. J. W. BYRDE, B.Sc. (Hort.), Ph.D.
A. T. K. CORKE, B.Sc.
A. H. FIELDING.
MRS. P. M. FOWLES (née Tozer) (*Resigned* 31 *December*, 1953).
MISS M. MARLOW.

*Special Colonial Office grant for studies of spray retention.
†Special grant from Rubber Research Institute of Malaya.

LIST OF STAFF—*continued.*

Cider and Fruit Juices :	A. Pollard, M.Sc., Ph.D.
	Miss M. E. Kieser, B.Sc., A.R.I.C. (Chemistry).
	L. F. Burroughs, B.Sc., A.R.I.C. (Chemistry).
	F. W. Beech, B.Sc., A.R.I.C. (Microbiology).
	C. F. Timberlake, M.Sc., A.R.I.C. (Chemistry).
	J. D. Phillips, B.Sc. (Biochemistry) (*Died 5 November*, 1953).
	J. G. Carr, B.Sc. (Microbiology).
	R. J. Hathway (Cider-maker).
	J. H. Llewellyn.
	Miss J. H. Baker.
	Miss Y. P. May.
	Miss M. R. Moseley.
	R. A. Coggins.
	P. E. W. Rodgers.
	Miss J. M. Lovell.
	G. Bradshaw.
Domestic Food Preservation :	Miss B. A. Crang, B.Sc.
	Miss M. Sturdy, B.Sc. (H. & S.S.).
	Miss M. Johnstone, B.Sc. (H. & S.S.).
	Miss S. J. Perkins, B.Sc. (*Appointed* 19 *January*, 1953).
	Miss B. C. Hart (*Resigned* 31 *August*, 1953).
	Miss M. M. Hooper.
Willows :	K. G. Stott, B.Sc.
Statistics :	G. M. Clarke, B.A., Dip. Stat. (*Appointed* 1 *July*, 1953).
Technical Section :	M. Greenwood, O.B.E., M.Sc.
	G. E. Clothier (Station Guide and Meteorological Recorder).
Library :	G. T. Spinks, M.A. (Honorary Librarian) (*part-time*).
	Miss I. E. Taylor.
Laboratory Staff :	F. E. Maltby (Chief Laboratory Steward).
	M. S. Calway.
	G. Kitchingham.
Photography :	G. H. Jones, A.R.P.S.
	E. R. Wilkins.
Plantations and Greenhouses :	E. W. Hobbis, B.Sc., N.D.H. (Plantations Officer).
	S. H. Legge (Marketing Officer and Recorder).
	E. Catlow (Recorder).
	A. I. Campbell, N.D.H. (Propagator and Recorder).
	R. M. Jarrett (Recorder).
	C. W. Harper (Spraying Recorder).
	D. W. Burd (Recorder).
	A. J. Hurdle (Plantations Foreman).
	H. Locke (Horticultural Assistant).
	Mrs. R. Lewis (Assistant Recorder).
	J. G. Clarke (Greenhouse Foreman).

Workshops and Maintenance :	S. E. Cole. H. J. Jones. B. F. Shearn. L. W. French.
Canteen :	Mrs. N. M. King.
Administrative and Clerical Staff :	R. A. Merchant (Chief Clerk, Accounts). D. H. Pittman (Cashier). Miss M. H. Simpson (Director's Secretary). J. Packer (Senior Clerk). Miss E. M. Matthews. Miss V. E. R. Alsop. Miss B. J. Haysham. Miss N. K. Bullock. T. J. Ford (*On National Service from 20 October*, 1952). Mrs. B. E. Stiddard (née Chapman). Miss S. R. Littlewood. Miss D. M. Smith.
Outdoor and Cider House Staff with more than 20 years' service :	R. Jones (31). J. C. W. Barnes (25). W. M. Hynam (25). F. W. Hynam (24). K. J. Escott (23).

Agricultural Research Council Unit of Plant Nutrition (Micro-Nutrients).

Honorary Director :
Professor T. Wallace, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

E. J. Hewitt, B.Sc., Ph.D., A.K.C. (*Seconded to Unit*).
*D. J. D. Nicholas, B.Sc., Ph.D., A.K.C.
W. Plant, B.Sc. (Hort.), Ph.D., N.D.H.
A. H. Williams, M.A., B.Sc.
W. A. Forster, B.Sc. (*Resigned* 24 *October*, 1953).
C. C. McCready, M.A., D.Phil. (*Resigned* 31 *October*, 1953).
Mrs. A. H. James, B.Sc. (Hort.).
D. F. Day, B.Sc. (Hort.) (Greenhouse Experiments Officer) (*Resigned* 12 *September*, 1953).
C. S. Gundry, S.D.H. (Greenhouse Experiments Officer) (*Appointed* 16 *November*, 1953).
W. J. Redmond.
D. J. Fisher.
D. G. Hallas.
B. A. Notton.
H. M. Webber.
Mrs. S. M. Taylor.
M. A. Wright.
Miss R. A. Paget.
R. T. Dewell (*Resigned* 12 *September*, 1953).
J. Jarrett.
Miss J. R. Brown.
Graham H. Jones.
M. W. J. Heyes.
Miss J. E. Mores (*Resigned* 30 *April*, 1953).
D. A. Lewis.

*From 18 September, 1952, temporarily attached to the McCollum Pratt Institute, Johns Hopkins University, Baltimore, Maryland, U.S.A., during the tenure of an E. J. Johnson Fellowship.

CONTENTS.

PAGE

Introduction .. .. *T. Wallace, Director* 9

Jubilee Celebrations .. .. *M. Greenwood* 29

Pomology:—

Virus diseases of fruit trees: IV. Further observations on rubbery wood, chat-fruit and mosaic in apples .. .. *L. C. Luckwill* 40

The use of apomictic seedling rootstocks for apples: Progress report *L. C. Luckwill and A. I. Campbell* 47

2:4:5-TP as a fruit-ripening agent: I. Apple var. Worcester Pearmain *D. L. Abbott* 53

Growth substances as fruit-thinning agents for apples: Progress report *D. L. Abbott* 58

A survey of perry pears in the West Midlands: I. North-west Gloucestershire *R. R. Williams* 64

Perry pears and their characters: I. .. .. *R. R. Williams* 70

The propagation of gooseberries: I. Some factors influencing the rooting of hardwood cuttings .. .. *Barbara A. Rake* 79

The infection of apple stems through wounds caused by geese *E. W. Hobbis and R. W. Marsh* 89

Plant Nutrition: Fruit:—

The use of iron chelates for the control of lime-induced chlorosis in fruit: Progress report I .. .. *C. Bould* 91

Plant Pathology:—

The effect of chemical structure on biological activity: the significance of chlorine in certain insecticides, fungicides and plant growth-regulators *D. Woodcock* 96

Application of the radioactive tracer technique to problems in plant nutrition and crop protection .. .. *W. D. E. Thomas* 102

The fungicidal properties of coal tar distillates .. *G. V. Coles and R. J. W. Byrde* 109

Spray application problems: VII. The determination of DDT in plant materials.. .. .. *J. T. Martin and R. F. Batt* 121

Spray application problems: VIII. The control of apple and plum aphides by DDT and BHC spring washes .. .. *S. H. Bennett* 129

Spray application problems: IX. Observations on the time of application and influence of site of deposition of BHC on the control of apple sawfly (*Hoplocampa testudinea* Klug.) .. .. *S. H. Bennett* 135

Spray application problems: X. The effects of spraying techniques on the control of some fruit insects. Lance and air-flow mist spraying *H. G. H. Kearns and N. G. Morgan* 139

Spray application problems: XI. A note on the preparation of a combined DDT-gamma BHC emulsion of high wetting properties as a substitute for winter washes .. .. .. *H. G. H. Kearns and N. G. Morgan* 146

Spray application problems: XII. Further field experiments on the control of apple scab by small-volume sprays *H. G. H. Kearns, R. W. Marsh and N. G. Morgan* 149

Blackcurrant leaf spot: I. Studies of perennation and infection *A. T. K. Corke* 154

The role of eradicant fungicides in the control of apple canker: II. *R. J. W. Byrde and A. T. K. Corke* 159

Observations on the sporulation of *Sclerotinia fructigena* on mummified apples and plums in late spring and summer .. .. *R. J. W. Byrde* 163

Spraying experiments against apple and pear scab at Long Ashton, 1953 *R. J. W. Byrde, A. H. Fielding and C. W. Harper* 167

CONTENTS—*continued.*

PAGE

Cider and Fruit Juices :—

Problems of microbiological control in cider-making .. *F. W. Beech and A. Pollard* 171

The composition of the juices of some varieties of cider apples *L. F. Burroughs and Yvonne P. May* 178

The role of nitrogen and vitamin B_1 in cider-making *L. F. Burroughs and A. Pollard* 184

Factors affecting the quality and stability of concentrated fruit juices : I. Blackcurrant and apple concentrates *Margaret E. Kieser, A. Pollard, C. F. Timberlake and Mary R. Moseley* 189

Domestic Food Preservation :—

A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report IV. .. .. *Alice Crang and Margaret Sturdy* 199

Notes on domestic meat and poultry preservation .. .. .. *Alice Crang* 206

Meteorology :—

Meteorological records, 1953 .. .. *G. E. Clothier* 208

Paper from the A.R.C. Unit of Plant Nutrition (Micronutrients) :—

The molybdenum requirements of tomato plants given different types of nitrogen supply in sand culture .. .. *E. J. Hewitt and C. C. McCready* 209

Publications, 1953 214

Copyright of all articles and illustrations in this Report reserved by the University of Bristol Agricultural and Horticultural Research Station, Long Ashton.

INTRODUCTION.

By T. WALLACE, Director.

Nineteen-fifty-three will long be remembered by the people of the British Commonwealth of Nations as the Coronation Year of Her Majesty Queen Elizabeth II. This historical event took place on June 2nd, and was the occasion of nation-wide rejoicing.

For the Institute also the year was a memorable one as marking the Jubilee of the foundation of the National Fruit and Cider Institute in 1903. This great occasion in the life of the Station was commemorated by appropriate celebrations in July which were organised jointly by the University and the National Fruit and Cider Institute, and at which the parent body of the Institute—the Bath & West & Southern Counties Society—the County Councils associated with the Institute, the Ministry of Agriculture and the Agricultural Research Council were officially represented. The official ceremonies included the presentation to the Institute by the Bath & West Society of a memorial plaque to record the part played by the Society in the establishment of the Institute and the continuous collaboration that has ensued between the Institute and the Society over the fifty year period.

The anniversary was also marked by the publication, by the University, of a commemorative volume " Science and Fruit," which records the establishment and history of the Institute over the fifty years and includes the Jubilee Lecture given by Lord Rothschild, Chairman of the Agricultural Research Council, and a number of special articles relating to various subjects that have comprised major studies at the Station during the period.

A separate report on the celebrations appears on page 29.

In view of the fact that 1953 was the Jubilee Year of the Station, the Director was invited to undertake the organization of the 6th Annual Symposium of the Colston Research Society, a society which for many years has been prominent in Bristol for the part it has played in supporting research work in the University. The symposium was held from 23rd to 27th March, 1953, at Manor Hall, one of the hostels of the University.

The subject chosen was " Insecticides and Colonial Agricultural Development," and the programme included a variety of topics so as to provide for the wide interests of the various colonies and of the attending members.

In selecting speakers and subjects for discussion we would wish to acknowledge the generous help and collaboration of Sir Geoffrey Clay and his scientific colleagues in the Colonial Office, and of Sir William Slater and scientific officers of the Agricultural Research Council. It was also pleasing to have the full and ready co-operation of the Association of British Insecticide Manufacturers, whose participation in the symposium was most valuable.

Ninety-four invited members took part in the symposium ; they included representatives of the French and Belgian Ministries of Agriculture, the Colonial Office, the N.A.A.S., the University, research stations both in this country and abroad, and commercial organizations concerned in the manufacture and distribution of insecticides. Sixteen papers were contributed, covering the main diseases of crops and stock in the Colonial territories, caused by insects or with which insect pests are associated, and the problems of their prevention and control by insecticides.

An outstanding feature of the conference was the excellent discussions that followed each paper, and members particularly welcomed the opportunity afforded to meet and consider their common problems from so many angles.

The Director acted as Symposium Director and the arduous secretarial duties were undertaken by Dr. J. T. Martin, who was largely responsible for the excellent arrangements made both for the smooth working of the programme and the comfort of members.

The proceedings have been published in book form, edited jointly by the Director and Dr. Martin, as Volume VI of the series of The Colston Papers.*

Sir Edward Salisbury, C.B.E., Sec.R.S., and Director of the Royal Botanic Gardens, Kew, graciously accepted the invitation of the Society to fulfil the role of guest speaker of the symposium and in this capacity addressed the Annual Banquet of the Society on March 25th.

Close co-operation has been maintained with the N.A.A.S. throughout the year. The annual refresher course for N.A.A.S. Horticultural Officers was held at the Station during July. In addition Dr. Kearns gave two courses at the Station on methods of spraying fruit plantations for the special benefit of Enforcement Officers of the Ministry of Agriculture. The Pruning Course was not held as in previous years as the N.A.A.S. wish to hold instead a course on propagation, which is planned to take place in the spring of next year.

The Director continued to act as Chairman of the N.A.A.S. Fruit Group, which is responsible for the Ministry of Agriculture publications on fruit culture, and of the Fruit Working Party responsible for the planning of fruit experiments at the Ministry's Experimental Horticulture Stations. He also continued to serve as a member of the Advisory Committees of some of these stations.

In July the Director accepted the invitation of the Minister of Agriculture to serve as a member of the Agricultural Improvement Council, and later was appointed chairman of the Horticultural Committee of the Council, which is responsible to the Council for the programmes of experiments undertaken at the Experimental Horticulture Stations. He ceased to serve as a member of the Plants and Soils Committee of the A.R.C. on completing the recognised period of service.

A meeting of the Cider Advisory Committee was held at Long Ashton on 16th March, 1953, which members of the Cider Orcharding Sub-Committee were invited to attend. Consideration was given to a suggestion from the Bath & West Society that a fact-finding survey of the problems of cider apple production might be instituted by the committee. Arising from the meeting the Society was referred to data already in existence and the magnitude of the task was stressed : it was agreed that the subject was too extensive to be undertaken with the resources available. The Station was subsequently asked to contribute an article on cider for inclusion in the Society's series of publications, and this is now in hand.

The Cider Manufacture Sub-Committee of the Cider Advisory Committee met on 3rd November to consider the draft programme of research for the Cider and Fruit Juices Section, which was approved for submission to the A.R.C. ; problems arising from metallic contamination in cider and cider fruit were also discussed on this occasion.

*" Insecticides and Colonial Agricultural Development " : Wallace and Martin : Proceedings of the Sixth Symposium of The Colston Research Society, 1953. Butterworths Scientific Publications, 1954 (pp. 180).

The Panel established by the Cider Advisory Committee for the Training of Cider Judges met in the Cider Section of the Bath & West Show on 3rd June, when tasting tests on the competition ciders were carried out after the official judging.

On the recommendation of the Management Committee of the Institute at its meeting at the University on 22nd July, the Memorial Studentship in Cider-making was awarded to Mr. J. B. Howell, a nominee of Somerset County Council, for a six-months' period from 1st October, 1953.

The Institute provided a small quantity of Kingston Black cider for a lunch held on the occasion of the unveiling of a plaque on the site in Manor Road, Old Woodstock, where George Kempster, a tailor, produced the first seedling of the Blenheim Orange apple in the 18th century.

Sir John Simonsen, Chairman of the A.R.C. Conference on Cider and Fruit Juices, paid his annual visit to the Station in November to discuss with Dr. Pollard and his staff the work in progress. As on previous occasions the discussions that took place were very helpful to the staff, who wish to record their thanks to Sir John for his continued interest in their work.

In the Section of Insecticides and Fungicides work on the fungicidal properties of tar oil washes was continued on behalf of the Rubber Research Institute of Malaya. Substantial progress has been made in these investigations and it is expected that the work will be completed by July 1954, when the grant-in-aid is due to terminate.

Steady progress has been made in the new work on Meat Preservation, undertaken in the Section of Domestic Food Preservation at the request of the Ministry of Agriculture, and preparations have been made to hold the first series of courses on the subject early in 1954.

Mr. S. T. C. Wright's tenure of the Boots' Scholarship ended on 31st August, but he was provided with a grant by the A.R.C. to enable him to complete the work he had been carrying out in the Pomology Section during the past two years. The third scholarship has been awarded, for two years from 1st September, 1953, to Mr. J. M. Rayner, B.Sc., who is working on problems of Button-top Midge damage to willows, under the direction of Dr. Kearns.

Members of the Station staff whose work involves journeys to outlying experimental plots and other research centres, have benefited from the provision by the A.R.C. of a Ford Estate Car, which is particularly useful for the transport of equipment and materials.

Mr. G. T. Spinks retired from his post as Plant Breeder on September 30th, on reaching the age limit. He had been on the staff of the Station since 1915. An appreciation of his services to the Institute is given later in this report.

During the year the Institute suffered the loss of a very old friend by the death of Mr. Godfrey Lipscomb. Mr. Lipscomb had been associated with the work of the Institute, through the Bath & West Society, since its establishment in 1903 and had served as a Governor since 1942. He had always been a regular attender at Institute functions and was at all times a staunch supporter of the Institute's work on the Council and Committees of the Bath & West. Cider was a very special interest with him, and as a member of the Journal and Education Committees of the Bath & West he was for many years closely connected with the joint experiments carried out by the Institute and the Society.

It is with deep regret that we record the death from poliomyelitis on 5th November of a member of the scientific staff, Mr. J. D. Phillips, after a very short illness. Mr. Phillips joined the staff of the Cider and Fruit Juices Section on 1st August, 1951, as Biochemist, after graduating in Bristol University, and had already made valuable contributions to the work of the Station, where his loss has been felt most keenly. Our sympathy is extended to his widow and small daughter in their very sad bereavement.

We are also very sorry indeed to record the passing, early in 1953, of Mr. H. P. Hutchinson, at the age of 79. Mr. Hutchinson was Willow Officer at the Station from 1922 until his retirement in 1939 ; as he continued to live nearby, his association with the Station was maintained to the end.

Staff.

Staff changes during the year were as follows :—

Appointments to scientific staff.

Mr. G. M. Clarke was appointed to the newly-created post of Statistician on 1st August, 1953. Mr. Clarke is a mathematics graduate of Oxford University, to which he returned, on completion of his National Service with the R.A.F., to take a further course of study leading to the University Diploma in Statistics, which he obtained in June 1953. Since his appointment he has received further training in the application of statistical methods at East Malling Research Station under Dr. S. C. Pearce.

Mr. D. G. Hill-Cottingham was appointed to succeed Mr. Tolhurst as Chemist in the Nutrition of Fruit Plants Section as from 1st August, 1953. Mr. Hill-Cottingham had been a student at the Northern Polytechnic, London, where he obtained a B.Sc. (Special) Degree in Chemistry, before proceeding to University College, London, for a course in biochemistry, as a result of which he was awarded the degree of M.Sc. (Biochemistry) in July 1953.

Dr. R. A. Webb was appointed to the staff of the A.R.C. Unit of Plant Nutrition as from November, 1953. Dr. Webb graduated in Botany at Oxford University, after which he was awarded a three-year scholarship by the Agricultural Research Council, followed by a one-year grant from the Department of Scientific and Industrial Research. Under these two grants he worked first in the Department of Botany at Oxford, carrying out research into the physiology and biochemistry of fungi, and then at the London School of Hygiene and Tropical Medicine, under Professor Raistrick, F.R.S. As a result of these investigations he was awarded the degree of D.Phil. Oxford, In 1941 he began work under a grant from the Medical Research Council, and in 1944 became established on the permanent staff of that Council and attached to the Human Nutrition Research Unit. On behalf of the Council he visited Basutoland, South Africa, to enquire into the increase in incidence of Pellagra, and was subsequently transferred to the Gambia, British West Africa, to carry out experiments on soil deficiencies with a view to improving the nutritional status of the population. From that time he has continued to work on problems of trace element deficiencies in crops in the Gambia, and since his work had become largely concerned with agricultural research, he was transferred from the Medical Research Council to the Agricultural Research Council, and finally attached to the Unit at Long Ashton. Since his transfer to the A.R.C. he has spent some of his leave working at Long Ashton, and is now completing a

final tour of duty in the Gambia, at the request of the Colonial Office, before taking up his duties at Long Ashton.

Appointments to assistant staff.

Mr. C. S. Gundry, Assistant Experimental Officer, was appointed to the post of Glasshouse Officer, A.R.C. Unit of Plant Nutrition, on 16th November, 1953, in succession to Mr. Day. After service as a Radio Mechanic in the Royal Navy, with the rank of Acting Petty Officer, Mr. Gundry began training in horticulture, first commercially and then with the Edinburgh and East of Scotland College of Agriculture, where he gained the Scottish Diploma in Horticulture, with Honours, in 1950. He subsequently gained further commercial experience before being appointed to the staff of the Essex Institute of Agriculture in 1951.

Miss S. J. Perkins, Assistant Experimental Officer, was appointed to a new post in the Domestic Food Preservation Section on 19th January, 1953, to undertake work in connexion with the preservation of meat and poultry. Miss Perkins came to us after graduating B.Sc. (Honours) in Botany at Bristol University in July 1952.

Miss E. M. Filer, Assistant (Sc.), Domestic Food Preservation, from 1st September, 1953, in succession to Miss Hart.

Mr. D. E. Aliband, Assistant (Sc.), Entomology, from 28th September, 1953.

Miss C. Byrne, Assistant (Sc.), Domestic Food Preservation, from 1st October, 1953.

Miss V. W. Rogers, Assistant (Sc.), Organic Chemistry, from 1st November, 1953.

Mr. J. S. Challice, Assistant (Sc.), Organic Chemistry, A.R.C. Unit of Plant Nutrition, from 12th October, 1953.

Mr. G. L. Mabey, Assistant (Sc.), Chemistry, A.R.C. Unit of Plant Nutrition, from 7th October, 1953, in succession to Mr. R. T. Dewell.

Miss J. R. Brown, Assistant (Sc.), was transferred from Soil Metabolism Investigations to the A.R.C. Unit of Plant Nutrition on 1st June, 1953, to succeed Miss Mores.

Retirement.

Mr. G. T. Spinks, Plant Breeder, retired from his post of plant breeder on reaching the age limit, on 30th September, 1953.

He joined the staff of the Station on 1st March, 1915, after coming to Long Ashton in 1914 on the completion of his three-year tenure of a Board of Agriculture and Fisheries Scholarship at Cambridge, where he worked under Professor Biffen : he had previously graduated in the Natural Science Tripos, Part I, at Cambridge and obtained the University Diploma in Agriculture. He had thus completed over 38 years of continuous service as a member of the Long Ashton staff.

During his period of service Mr. Spinks held successively the posts of research assistant in mycology (1915–1919), botanist (1919–1924) and plant breeder (1924–1953). During the greater part of this time he also acted as honorary librarian, and in this capacity he has been responsible for the building up of the library from a very small unit to its present large size.

It is as a plant breeder that Mr. Spinks' name will be remembered by horticultural scientists and fruit-growers alike, as a number of his fruits during

recent years have found a place in commercial fruit culture. The best known of these are undoubtedly his blackcurrant varieties Mendip Cross, Cotswold Cross and Malvern Cross, all of which appear in the general nursery catalogues. One other soft fruit introduced by Mr. Spinks, the blackberry Ashton Cross, has attracted the attention of commercial growers, but so far it has not been grown extensively.

Among the tree fruits he raised two gained Awards of Merit of the Royal Horticultural Society in 1953—the pear Bristol Cross and the plum Severn Cross. Other tree fruits of merit bred by Mr. Spinks, though not yet grown to any large extent in commercial orchards, are as follows :—

Apples : Exeter Cross, dessert, mid-August ; Cheddar Cross, dessert, late August–early September ; Taunton Cross, dessert, September–early October ; Worcester Cross, dessert, early October.

Pears : Cheltenham Cross, dessert, early to mid-September.

Plums : Teme Cross, dessert, late August ; Thames Cross, dessert, early–mid-September ; Frome Cross, culinary, mid-late September.

In addition to the above-named varieties there are still many seedlings bred by Mr. Spinks under test, from which it is hoped other valuable fruits will be selected by his successor.

It is pleasant to report that Mr. Spinks will remain with us for the next two or three years as librarian, on a part-time basis. This arrangement will ensure continuity in library matters and will, we hope, enable us to draw on his wide experience in assessing the qualities of some of his more recent seedlings.

Resignations.

Mr. J. A. H. Tolhurst resigned from his post in the Soils and Plant Nutrition Section on 28th February, 1953, to take up an appointment with the Tea Research Institute of Ceylon. Most unfortunately, a short while after arriving with his wife and family in Ceylon, he contracted a severe attack of poliomyelitis ; we are glad to learn that he is now well on the way to recovery.

Mr. W. A. Forster resigned from the post of Chemist in the A.R.C. Unit of Plant Nutrition on 24th October, 1953, to take up an appointment with Messrs. Albright & Wilson Limited, Chemical Manufacturers of Birmingham.

Dr. C. C. McCready, Physiologist, A.R.C. Unit of Plant Nutrition, resigned from 31st October, 1953, to return to Oxford to take up an appointment under Professor Blackman in the A.R.C. Unit of Agronomy.

The following assistant staff resigned on the dates shown :—

Mr. D. F. Day, Greenhouse Officer, A.R.C. Unit of Plant Nutrition, 12th September, 1953.

Miss J. E. Mores, Assistant (Sc.), A.R.C. Unit of Plant Nutrition, 30th April, 1953.

Miss B. C. Hart, Assistant (Sc.), Domestic Food Preservation, 31st August, 1953.

Mr. R. T. Dewell, Assistant (Sc.), A.R.C. Unit of Plant Nutrition, 12th September, 1953.

Mr. R. E. Monro, Ungraded Temporary Assistant, Nutrition of Fruit Plants, 31st July, 1953.

Administrative Staff.

Appointment. Miss M. J. Hathway as Shorthand-Typist, with effect from 1st January, 1953.

Temporary Workers.

Dr. H. Gleen, a member of the A.R.C. staff, who had been accommodated at the Station since 1947 for work on Soil Metabolism Investigations, resigned with effect from 31st December, 1953.

Miss P. Miles, N.A.A.S., was transferred to the Experimental Horticulture Station, Kirton, Lincolnshire, where she will continue her work on bulb nutrition.

Visits Abroad.

At the request of the Johns Hopkins University, Baltimore, U.S.A., Dr. D. J. D. Nicholas, A.R.C. Unit of Plant Nutrition, was granted an extension to his special leave to continue his work at the McCollum Pratt Institute for a further year from September 1953.

Dr. A. Pollard attended the International Federation of Fruit Juice Producers Conference in Paris on 23rd and 24th March, 1953, where he contributed a paper entitled " The use of ion exchangers in the manufacture of fruit juices."

Miss B. A. Crang attended the Eighth International Congress on Home Economics at Edinburgh from 12th to 18th August, 1953.

Miss A. Rake spent two months from mid-April to mid-June in Holland at the Laboratorium Tuinbouwplanteelt, Wageningen, in exchange with Miss J. C. Baars, who worked at Long Ashton in the Pomology Section during that period. Miss Rake's work in Holland was mainly concerned with the techniques for experimental pollination of fruit trees.

Degrees, Honours, etc.

The Director was elected to the Fellowship of The Royal Society in March.

He received the Victoria Medal of Honour of the Royal Horticultural Society, awarded in 1952, in February.

The degree of Ph.D. in Bristol University was awarded to Mr. W. A. Forster for his thesis entitled " Some toxic effects of heavy metals on crops grown in soils," which was completed before he left Long Ashton in October.

A book entitled " Chemical Tissue Tests for determining the Mineral Status of Plants in the Field," by Dr. D. J. D. Nicholas, was published by The Tintometer Limited of Salisbury.

Buildings and Land.

During the year the small building projects mentioned in the 1952 Report, for which sanction had been given by the Ministry of Agriculture, were all proceeded with. The Biology store, which is to provide temporary laboratory accommodation, was completed in the late summer and was equipped and fully occupied during the autumn. The cloakroom extensions in the main building and the extensions to the new farm buildings were also completed.

In June the Ministry of Agriculture was able to sanction in principle the Station proposal to erect a large block of greenhouses combined with a number

of special purpose laboratories, and the University was asked to proceed with the preparation of detailed plans with a view to beginning the actual building operations in the summer of 1954. These preparations are now well advanced, and it is hoped it will be possible to proceed with the work according to schedule.

This greenhouse unit will provide badly needed facilities for the sections of Pomology, Plant Nutrition, Plant Pathology, Entomology and Insecticides and Fungicides. It will also include special accommodation for photography and for work with radio-active isotopes.

Much work has also been done on general maintenance, the main items being the painting of glasshouses, the painting and decoration of the main office building and of some of the dwelling houses, and the concreting of areas near the main entrance and at the junction of the drive leading to the farm buildings and Director's House with the main road.

On the farm, clearing operations were extended to Plot 22 (apple rootstock plot). The clearing of this plot will be completed during the next two winters.

The strawberries on the manurial plots (Plot 12) were ploughed in after fruiting, having occupied the land since 1950. This area will be cropped with vegetables for two or three years in preparation for further strawberry trials.

Further plantings of dwarf pyramids were made on Plots 13 and 16, towards the completion of the block of 5,000 pyramids required for spraying trials. Only 326 trees remain to be planted under this scheme.

New plantings of blackcurrants have been made to initiate new work on automatic spraying methods, variety performance and manurial problems.

A block of Leveller gooseberries has been planted for Gooseberry Mildew investigations, and a small area of raspberries for work on spray residues.

Research Activities.

Plant Nutrition : Fruit.

Pot experiments, using radioactive phosphorus, showed that when a grass cover crop was cut frequently and the cuttings allowed to decompose *in situ* the uptake of fertilizer phosphorus by Malling I rootstocks was 37% greater than in the absence of a cover crop, provided supplies of nitrogen and other nutrients were adequate. In the absence of adequate supplies of nitrogen grass reduced total dry matter production, total phosphorus and fertilizer phosphorus uptake. Orchard experiments, extending over a period of six years, have shown that, in comparison with clean cultivation or annual cover crops, a grass cover increased the potassium and phosphorus status of apple leaves and decreased their nitrogen status.

The iron chelate of ethylenediaminetetraacetic acid (Fe-EDTA) has been used in attempts to control lime-induced iron chlorosis in redcurrants, plums and pears. Soil treatment was not effective at levels of 5 to 30 g. of chelated iron per tree : foliage sprays were more promising but caused leaf scorch at concentrations above 0·1%.

A detailed study of the changes in the nitrogen and mineral nutrient status of blackcurrant leaves with regard to age and position showed that the use of leaves for critical comparisons from the middle third region of the current year's growth was justified.

The analysis of leaves from the strawberry (*var.* Climax) manurial experiment showed that the omission of phosphate caused a significant decrease in

leaf phosphorus at the end of the first season (1950), at the last sampling date in 1952 and at the first and second sampling dates in 1953, as compared with NPK treatment. All values, however, were above the threshold level and omission of phosphate had no significant effect on yield of fruit although after thirty years' treatment the soil phosphate values on omit P plots had been reduced to one-third of the level on NPK plots. Omission of potassium had a serious deleterious effect on growth, yield and quality of fruit ; omission of nitrogen reduced growth and yield of fruit without affecting quality. The average yields of grade I fruit in tons per acre for the three years 1951–3 have been : NK (5·68), NPK (5·37). FYM (5·31) > PK (4·68), NP (3·58) and N (3·47). The experiment is to be repeated using Royal Sovereign in addition to Climax in order to compare the effects on a less vigorous variety.

Krilium (CRD 189) had a significant effect on the percentage aggregation and water stability of a silty loam soil at Long Ashton but had no significant effect on the yield or leaf nutrient status of strawberry, *var.* Climax, in the presence or absence of a complete fertilizer (NPK).

Pomology and Plant Breeding.

A new dessert apple, earlier than Worcester Pearmain, has been named Exeter Cross. Its parentage is Worcester Pearmain × Beauty of Bath.

The presence of at least five auxins and two growth inhibitors has been demonstrated in ether extracts of apple fruits at different stages of development from bud burst to harvest. An acid auxin, R_F value 0·4 in butanol/ammonia, was found at all stages except full bloom ; its absence from Lord Lambourne apples infected with " chat-fruit " virus suggests that it may be associated with fruit growth and ripening. Two other acid auxins, with R_F values of 0·1 and 0·8, were found in the seeds ; the second is believed to control fruit drop. Two neutral auxins were also found in seed and young fruits.

Blackcurrant fruits have been found to contain two acid auxins, one of which is almost certainly indolyl acetic acid ; a neutral auxin, with the same R_F value as indolyl acetonitrile, and an acid inhibitor. The " running-off " of blackcurrants is thought to be a natural fruit-drop associated with a period when the acid auxins are at a low level.

Further trials of NAA as a fruit thinning agent were made with apple varieties Lane's Prince Albert, Early Victoria and Laxton's Superb. Thinning was found to bring no compensatory increase in fruit size and the result was a loss of marketable crop.

2:4:5 trichlorophenoxy-propionic acid again proved successful as a ripening agent for Worcester Pearmain apples, enabling good quality fruit to be marketed twelve days earlier than normal. Its use is being extended to other varieties of apple and to other types of fruit.

An account is given in the present volume of trials with two apomictic species of *Malus* that show promise as seedling rootstocks for apples. Tests of seven clonal rootstocks for the presence of " chat-fruit " virus are also described. The highest degree of infection was found in M IV ; some infection was also found in M XII and M XVI. Rootstocks M I, II, VII and IX were free of this virus, which appears to be less widely distributed than that causing rubbery wood.

As a result of the increased interest in perry, a survey has been made of the perry pears of Gloucestershire. The pomological characters of some of the varieties are described in the present volume, and a list of recommended names and their synonyms is given.

Pests and Diseases and their Control.

Further work has been carried out on the effect of changes in the structure of organic compounds upon their activities as systemic fungicides or parthenocarpic agents. Certain dichloro-2-naphthols, 5:5-dimethyl-*cyclo*hexane-1:3-dione and its *p*-chloro-benzaldehyde and 2:4:6-trichlorophenoxy-n-propyl chloride derivatives showed systemic fungicidal activity equal or superior to that of 2:4:6-trichlorophenoxy acetic acid used as the standard in laboratory tests against chocolate spot of bean. Work with substituted 2-naphthyloxy aliphatic acids as parthenocarpic agents has shown the importance of the number and position of chlorine atoms in determining activity. Further study of the relationship between the fungicidal and phytotoxic effects of compounds related to dichloronaphthaquinone has shown a close correlation between the rates of hydrolysis of non-damaging esters and their fungicidal activity.

Progress has been made in characterizing the fungicidal components of tar-oil distillates. Maximum activity against the mouldy rot fungus of the rubber tree has been found to be associated with the high-boiling tar acids. The effect of neutral tar fractions was variable, depending upon the method of preparation of the parent tar. Tar bases, with one exception, showed no outstanding activity.

Radioactive tracers have been used in joint work with other sections. Further information has been obtained on the factors governing the absorption, translocation and breakdown of schradan in crop plants. In collaborative work with Seale Hayne Agricultural College it has been shown that with demeton, unlike schradan, there is little risk of the contamination of nectar, and consequently of honey.

Considerable attention has been paid to problems arising in the field application of spray materials. Methods have been devised by which copper and lime sulphur deposits are recorded on plaster of Paris plaques. These methods, with chemical determinations, have been used to investigate the extent, distribution and persistence of deposits from different spray formulations and methods of application on potato, tomato and other crops. The effect of stickers used with copper sprays has also been examined. A rapid method for the determination of DDT deposits has been developed and used successfully in the examination of foliage and fruits.

Studies have been made of the biology of leaf-curling plum aphid, mealy plum aphid and apple sawfly. In experiments on the placement of BHC on apple fruitlets for sawfly control it was found that application could not be delayed beyond egg-hatch and that to ensure a nearly complete control any application to the outside of the calyx should cover the oviposition scar.

The toxicities of a series of isosteres of DDT have been assessed, using *Dysdercus fasciatus* : the replacement of chlorine by methyl or hydroxyl was found to reduce toxicity. Further studies have been made of the inhibition of esterase preparations by para-oxon, parathion and related compounds.

A study of the " button-top " midge of basket willows has been begun with a view to devising methods of control.

Biological methods of evaluating the efficiency of fungicide distribution have shown that the "range of action" of small discontinuous deposits of copper suspensions is due to mechanical re-distribution by water. Lime sulphur deposits, however, may exhibit this "range of action" in the absence of a complete water film.

Comparative trials of small-volume air-flow mist sprays, using 80–100 gallons spray per acre, against conventional lance sprays, using 400 gallons of material of the same concentration, showed the small-volume application to be completely successful against leaf-curling plum aphid (0·05% DDT) and apple aphid (mixture of 0·05% DDT and 0·013% BHC) and to give commercial control of apple sawfly (0·013% BHC). Air-flow applications of copper fungicides at 40 gallons per acre promised ready control of potato blight.

Three successive small-volume air-flow applications of lime sulphur (¾%) with and without wetter (0·025% dioctyl sodium sulphosuccinate) failed to control either fruit-tree red spider mite, woolly aphid or apple scab, all of which were satisfactorily controlled by large-volume lance application using lime sulphur and wetter at the same times and concentrations. In other large-volume scab control experiments, SR 406 gave better control than lime sulphur and was non-damaging on Lane's Prince Albert.

The overwintering of the fungi causing apple mildew, blackcurrant leaf spot and *Gloeosporium* apple rot is being studied. Extensive cankers on Cox shoots have been induced by inoculations with *Gloeosporium perennans*, but few with *G. album*. In a joint experiment with Ditton Laboratory late summer spraying of Allington with SR 406 and ziram has given promising results in reducing *Gloeosporium* rots in storage.

A 0·3% phenyl mercury chloride spray applied to apple tree cankers caused by *Nectria galligena* suppressed sporulation but did not check the growth of the cankers. In a trial made in collaboration with the N.A.A.S. a March application of this spray to cankered Worcester Pearmain trees reduced to one-sixteenth the number of apples on these trees showing *Nectria* eye-rot in the following August.

Cider and Fruit Juices.

Cider. Further work has confirmed that the rate of fermentation of an apple-juice is dependent on its content of soluble nitrogenous substances and of thiamine (Vitamin B_1); the stability of naturally sweet centrifuged ciders is determined by a deficiency of these substances. The soluble nitrogen of the juice consists mainly of a number of amino-acids, of which asparagine is usually the chief component. The thiamine content of cider apple juices has been found to be extremely low, but amounts of the same order have proved effective in stimulating the growth of yeast in slowly fermenting juices.

In fresh apple-juices malic acid has been found to be the predominant organic acid, responsible for major variations in total acidity. Of the other acids quinic acid occurred in greatest amount, accounting for 30% of total acidity in some cider varieties. Juices from over-mature fruit contained lower levels of malic acid : where rotting had begun the breakdown of malic acid was accompanied by the appearance of citric acid, of galacturonic acid and poly-uronides from pectin breakdown, and of other unidentified acids. During fermentation the main changes in acid composition were the production of

succinic acid by yeast and the breakdown of malic acid to lactic acid by malo-lactic bacteria. Some instances of quinic acid metabolism have been noted and are being further investigated.

Further study has been made of pure yeast fermentations, whose application to cider-making offers some advantages in fermentation and in subsequent clarification. The simpler alternative procedure of using sulphur dioxide to suppress the less desirable members of the natural flora has been further developed and given practical application. Selected yeasts for conditioning cask ciders have also been tested in collaboration with the industry.

A long-term investigation of the yeasts and bacteria occurring in apple-juices and ciders has been undertaken. Methods of isolation have been designed, making extensive use of antibiotics and other compounds in the preparation of media for the selective separation of the different classes of organism. The classification of the yeasts and lactic acid bacteria is now in progress. Interest in the lactic organisms producing the condition of ropiness in ciders has been stimulated by the use of similar organisms in the manufacture of dextran.

Perry. Increased attention has been paid to problems in perry-making : a survey of perry varieties has been initiated ; extensive vintage trials have been made and investigations of the composition of pear juices and perries are being carried out. The chemistry of the organic acids and the phenolic components (tannins) of juices and perries has been studied first : it has been found that the characteristic hazes and deposits that arise in perries appear to result from changes in substances of leucoanthocyanin reaction that form the main component of the tannin fraction.

Unfermented Juice Products. Work with apple juice has been concerned with the oxidative changes and deposits arising in bottled juices on storage. The use of low concentrations of sulphur dioxide at the time of juice extraction has been found to inhibit oxidative changes and to reduce the amount of deposit formed on storage ; it may, however, have an adverse effect on flavour and aroma. The deposits in bottled juices have been found to consist mainly of protein and tannin materials.

Storage temperature has been found to have a marked effect on the quality of concentrated apple and blackcurrant juices. Apple-juice concentrates quickly become dark and develop off-flavours when stored at room temperature ; these effects may be avoided by storage at 0°C. In concentrated blackcurrant juices, which lose colour and ascorbic acid and undergo extensive flavour changes when stored at room temperature, there is considerable deterioration even at 0°C. ; the changes may be greatly inhibited by storing at deep-freeze temperatures (—23°C.).

In view of the present interest in the metallic contamination of foodstuffs an examination of the amounts of copper, zinc and iron occurring in unsprayed apples has been made. The amounts of copper and zinc in fruit and juice of the varieties tested were of the order of 0·5 p.p.m. ; the amounts of iron were more variable (1–3 p.p.m.), but on juice extraction most of the iron was retained by the pomace. There seems little chance that the levels of these metals naturally present in the fruit will exceed those likely to be made permissible by legislation in derived products.

Domestic Food Preservation.

Pressing demand by Women's Institutes for instruction in preserving

meat and poultry led to a request by the Ministry of Food that the Section undertake work on this subject. The proposal was approved by the Ministry of Agriculture in the autumn of 1952 and the subject has been given a high priority in the 1953 programme.

Investigations have been made of the times of processing necessary to destroy spores of bacteria of known heat-resistance in inoculated packs of chicken, pork and rabbit, and of the temperatures attained in the container throughout the process. From the calculated " lethal values " detailed requirements for processing these foods in various sizes of container have been worked out. Chicken and pork have also been preserved by deep freezing, and the quality assessed after intervals of storage.

Comparisons were made of the fresh fruit and preserving qualities of ten varieties of raspberries, grown at Starcross, Devon. One of the new varieties, Malling V, which grows well in the south-west, was judged the best as fresh fruit, but Norfolk Giant and Lloyd George were considered of better colour and flavour than any of the newer varieties when preserved by bottling or deep freezing.

Twenty-four varieties of plums were compared after preserving by deep freezing and by bottling. The frozen fruit was disappointing compared with last year's samples, probably due to slight modifications of the method of processing. The bottled fruit results were satisfactory and in general agreement with the findings of previous years for those varieties previously tested.

Willows.

The Station collection of 148 willow varieties was successfully transplanted to new beds in March. 61 reputed new varieties have been accommodated in trial beds pending a check of their identity.

Further information on the characters of the principal commercial varieties has been collected with the object of preparing a key for their identification. Surveys of the areas under basket and cricket bat willows have been continued.

Many growers are anxious to use mechanical cultivation for the difficult task of controlling weeds in willow beds. The rooting habits of basket willows are therefore being studied in order to determine planting distances best suited to this type of cultivation.

The willow industry has not been slow to take advantage of the resumption of the Station's advisory service. There were 193 requests for information during the year, the first since 1938 in which the services of a full-time adviser have been available.

Statistics.

Assistance has been provided to a number of sections in the design and layout of experiments, in the analysis of data from past experiments and in the interpretation and presentation of results ; a detailed examination of the data collected between 1927 and 1938 in the study of the effect of orchard factors on the keeping quality of fruit is in progress. A survey is being made of problems whose solution will help to make the best use of experimental material and labour.

Agricultural Research Council Unit of Plant Nutrition (Micro-nutrients).

Molybdenum Nutrition.

Investigations of the effects of nitrogen source on the molybdenum requirements of plants were continued, using tomato, a crop in which whiptail symptoms, used as criteria of molybdenum deficiency in previous experiments with cauliflower, do not occur.

Growth of tomato plants given nitrate, nitrite, ammonium sulphate, ammonium nitrate, ammonium nitrite, urea or glutamic acid was decreased in all instances when molybdenum was omitted. Chlorophyll was decreased by molybdenum deficiency in the presence of nitrate or ammonium nitrate and typical symptoms of molybdenum deficiency in tomato were observed only in these treatments. Ascorbic acid and dehydroascorbic acid were decreased by omission of molybdenum in all treatments, effects being greater with nitrate or ammonium nitrate. It is concluded that molybdenum is required by tomato irrespective of the form of nitrogen supplied in these experiments, but that the presence of nitrate induces specific deficiency symptoms and entails a higher molybdenum requirement.

Experiments on the effects of molybdenum status and nitrogen supply on the R.Q. in cauliflower leaves were repeated. Results obtained in 1952 were confirmed, namely the observation of an elevated R.Q. about 1·1 in molybdenum deficient plants given nitrate, compared with R.Q. values just below 1·0 for other nitrogen treatments or for material from plants grown with molybdenum. Injection of molybdenum into nitrate-grown plants caused a temporary further increase in R.Q. to 1·33 ; the increase was detected 1½ hours after adding molybdenum. There was no change in the R.Q. of plants grown with other sources of nitrogen.

Molybdenum deficiency produced an increase in the ratio of inorganic to organic phosphorus in the acid-soluble phosphorus fractions of cauliflower leaves and also increased the total phosphorus content of plants given ammonium compounds or urea. Adenylic acid and adenosine pyrophosphate in barium fractions were estimated by enzymatic methods of analysis. There was an increase in the concentration of adenylic acid and adenosine pyrophosphate when molybdenum was deficient, except with urea. The adenosine pyrophosphate occurred in an acid-insoluble barium fraction obtained from leaves. This observation confirms a recent independent report that compounds in plants related to adenosine triphosphate in animals behave abnormally during barium fractionation of plant extracts.

An investigation into the distribution of total molybdenum in different fractions of plant extracts has been begun ; methods are being developed to differentiate between anionic and cationic molybdenum and between its different valency states. Cauliflower and tomato plants fed with high concentrations of hexavalent molybdenum as molybdate appear to contain a large proportion of the total in the pentavalent state.

Effect of seed reserves.

Large seeded leguminous plants were again grown in sand culture from commercial seed and from seed saved from previous sand culture experiments where either a complete nutrient solution had been given or copper, zinc or molybdenum had been omitted. Growth of the plants was normal, irrespective of seed history, when a complete nutrient was given. Omission of copper,

zinc or molybdenum resulted in markedly decreased growth of plants produced from the respective deficient seeds compared with that of plants from the commercial or complete-nutrient-grown seed. There were cumulative effects of raising seed from successive generations of plants grown under deficiency conditions but no deterioration was evident in plants derived from seed raised under complete nutrient conditions for 3 years.

Soil Acidity.

The visual symptoms shown by a number of legumes : white clover, lucerne, red clover and subterranean clover, were determined on a strongly acid soil (pH 4·0), to which four treatments: nil, ground limestone, ground dolomite and gypsum, were applied.

Plants in the nil treatment were stunted and showed marked symptoms of aluminium and manganese toxicity ; plants receiving gypsum also failed and showed similar symptoms. Treatment with limestone and dolomite led to healthy growth. Subterranean clover was the most vigorous legume of the group and the best indicator plant, though no member was very satisfactory for purposes of visual diagnosis.

In the fourth year of an experiment on a site on the Lower Greensand (pH 4·5) symptoms of manganese toxicity were observed for the first time in the test-crop, lettuce. In the previous three years only molybdenum deficiency had been apparent in the various test-crops used. Treatment with limestone gave yields of up to 3 tons lettuce per acre, but contrary to previous results there was no response to sodium molybdate because of manganese toxicity.

Indicator plots in relation to copper deficiency conditions in sheep and cattle.

Indicator crop plots, including factorial fertiliser combinations of nitrogen, phosphate, potassium and copper, were continued for a second year at four centres at which conditioned copper deficiency occurs. At one centre a small experimental flock of ewes grazing the natural herbage around the plots showed a high incidence of swayback in their lambs. The indicator plants, however, showed only acute phosphate deficiency. Crops at the other centres also showed phosphorus, and sometimes nitrogen, deficiency. There were no responses to copper treatments.

Nutrition of Fungi, etc.

The nutrient requirements of several strains of *Azotobacter* and *Neurospora* have been further investigated under the direction of Dr. D. J. D. Nicholas, who was attached throughout the year to the McCollum Pratt Institute, Johns Hopkins University, Baltimore ; the effects of metal-induced iron deficiency in the second organism were also studied.

Work has been continued on the effects of heavy-metal toxicity in the tomato and of the effect of chelated iron on the induced symptoms of iron deficiency.

In collaboration with the Chemistry section a study is being made of the dust contamination of plant material ; comparative tests of the analytical methods in use at a number of research stations are being made. The correlation of tissue test methods, using various extractants, with the results obtained from the complete analysis of digested material has been further studied.

Organic constituents of plants.

Study of the phenolic substances of the apple and pear, especially those of leuco-anthocyanin type, continues. An interesting difference has emerged : while the leuco-anthocyanins of the cider apple can be separated by paper chromatography into discrete spots and are presumably of a molecular size comparable with catechins, those of the perry pear are of much greater complexity. No individual substances have been separated from the pear leuco-anthocyanins whose molecular complexity appears to be related to the frequent occurrence of clots and precipitates during perry making.

A study of the simpler organic constituents of the tomato plant, in relation to nutrient status, is in progress.

Other Activities.

Members' Day was this year combined with the Field Day arranged to celebrate the Jubilee on July 23rd,

Cider Sampling Day. The Annual Sampling Day was held on May 7th, when a series of ciders and perries was exhibited for sampling. Cider fruit of the 1952 crop gave juices higher in specific gravity than those of the previous season. In the 1952 season the fruit matured rapidly but the juices were slow in fermentation and it was necessary to add yeast nutrients to some of the ciders to complete the fermentations in time for Sampling Day.

In 1952 increased attention was given to perry-making and a range of perries was made from varieties collected from the old trial orchards planted by Long Ashton in 1910. The programme opened with a series of single variety and blended perries. These were followed by single variety ciders made from fruit varieties given in the Recommended List or showing special interest.

The ciders shown in the third section illustrated the use of temperature adjustment for the control of malo-lactic fermentations in cider-making, a topic that is now arousing increasing interest in the industry. These ciders were followed by a series fermented by different selected yeasts. The need for pure yeast fermentations in cider-making is by no means accepted and the ciders shown provoked interested comment. The morning programme ended with a series of ciders comparing the effects of champagnisation with those of carbonation.

In the afternoon members were shown exhibits in the Cider House and laboratories, and parties were conducted round the plantations to see work in progress, more especially a bush cider plot following thinning for automatic spraying, and the nursery propagation and building of cider trees.

Visitors.

The number of organised parties visiting the Station was fifty, seven more than in 1952. The full list is given below. Besides those attending courses in Domestic Preservation, Spray Hazards (Ministry of Agriculture) and the Refresher Courses arranged annually for Agricultural and Horticultural Officers of the N.A.A.S., it includes members of the Agricultural Improvement Council, of the Colston Research Society's Symposium, and of the Fruit Group of the Royal Horticultural Society.

Organised Parties, 1953.

Abona Ladies' Circle.
Agricultural Improvement Council.
Aireborough Grammar School, Leeds.
Bear Street Boys' School, Wotton-under-Edge, Gloucestershire.
Birmingham University Biochemical Society.
Bristol Corporation Gardening Class.
Bristol 41 Club.
Bristol Grammar School, Science Society.
Bristol Land Rangers.
Bristol University Staff.
Cabot Ladies' Circle, Loyal Order of Moose, Bristol.
Cheddar Growers.
Cheltenham Ladies' College.
Clifton College Science Students.
Colston Research Society Symposium Members.
Colston Primary School Geography Class, Bristol.
Crewkerne Grammar School for Boys, Somerset.
Diocesan Training College, Barrow Court.
Domestic Preservation Courses (2).
Easton Road Primary School Parents' Association.
Edison-Swan Horticultural Club.
Fairfield School Parents' Association, Bristol.
J. S. Fry & Sons Ltd., Somerdale, Foremen's Association.
German Young Farmers' Association.
Glamorgan Federation of Women's Institutes, Produce Guild.
Gloucester Training College for Domestic Science.
H.M. Stationery Office, Bristol.
Hereford Training College.
Imperial Tobacco Company Ltd., Research Department, Bristol.
Irish Young Farmers' Club.
Ladies' Redcliffe Guild.
Ministry of Agriculture and Fisheries—Spraying Courses for Enforcement Officers (2).
Ministry of Education, Rural Education and Agricultural Panels.
N.A.A.S. Officers and County Horticultural Instructors.
N.A.A.S. Horticultural Officers' Refresher Course.
N.A.A.S. Agricultural Officers, Eastern Province.
Norwegian Horticultural Students.
Portishead Modern School.
Reading University Horticultural Students.
Royal Horticultural Society, Fruit Group.
St. Gabriel's Training College, Camberwell.
Soroptimist Club of Bristol.
Southmead Young Mothers' Fellowship.
Two Mile Hill Parent-Teachers' Association, Bristol.
Waterperry Horticultural School.
Weston-super-Mare Grammar School for Girls.
Young Farmers' Club, Weston-super-Mare, Banwell and District.
Youth Hostels Association, South-West Region.

There was again a large number of visitors from overseas. Owing to lack of accommodation it was unfortunately not possible to receive all the overseas scientists who asked to work in the laboratories.

Visitors from Overseas, 1953.

Australia :

Mr. T. Chadwick, Melbourne.
Mr. R. G. Coleman, C.S.I.R.O., Brisbane.
Mr. W. A. Davis, Berri, South Australia.
Professor and Mrs. Dew, University of Sydney.
Mr. E. P. Keogh.
Dr. E. J. Loneragan, C.S.I.R.O., Canberra.
Dr. and Mrs. R. B. Madgwick, New South Wales.
Mr. W. P. Mair, Victoria.
Mr. Colin M. Mellor, Melbourne.
Mr. B. T. Overell, Monsanto Chemicals Ltd.
Mr. T. B. Paltridge, C.S.I.R.O.

Australia (cont.)	Dr. C. S. Piper, Adelaide.
	Mr. C. Plush, Berri, South Australia.
	Mr. J. K. Powrie, C.S.I.R.O., Adelaide.
	Dr. R. C. Rossiter, C.S.I.R.O., Perth.
	Mr. N. Tulloh, Australian Scientific Liaison Officer, London.
	Professor J. G. Wood, Adelaide.
Belgium :	Dr. G. van Hoeck, Heverlé.
	M. M. Laurent, Malines.
	Dr. L. van der Linden, Duffel.
	Dr. R. Piot, Herverlé.
	Dr. H. Questienne, La Hulpe.
Canada :	Mr. P. Dover, Ontario.
	Mr. W. B. George, Kempsville, Ontario.
	Dr. F. B. Johnston, Department of Agriculture, Ottawa.
	Miss L. C. Pepper, Department of Agriculture, Ottawa.
Ceylon :	Mr. D. M. Fernando, Rubber Research Institute.
Chile :	Mr. Alberto Matthei, Concepcion.
Denmark :	Mr. Erling Agger, Svinninge.
	Mr. Chresten Sørensen, Copenhagen.
Fiji :	Mr. N. G. Cassidy, Suva.
Finland :	Dr. T. F. Rautavaara, Helsinki.
France :	Dr. G. L. Ducet, Versailles.
Germany :	Mr. Eemingfeld, Bavaria.
	Dr. W. Helmerking, Leverkusen.
	Miss Julia Weyde, Brunswick.
Gold Coast :	Mr. H. R. Mapother, W.A.C.R.I., Tafo.
	Mr. D. Stephens, Department of Agriculture.
Holland :	Miss J. C. Baars, Wageningen.
	Mr. N. Feis, Wageningen.
	Miss A. C. van Schreven, Wageningen.
	Dr. L. W. Starkie, Deventer.
Iceland :	Miss K. Kristjansdotter.
India :	Mr. M. J. Green, Northern Assam.
	Mr. B. L. Marwaha, Kangra, Punjab.
Israel :	Dr. I. Peretz, Ministry of Agriculture.
	Mr. M. Sheffer, Habirya.
Italy :	Dr. E. Refatti, Pavia.
Jamaica :	Mr. E. J. Gregory, Agricultural Department.
	Mr. A. W. McIlwaine, Banana Growers' Association.
	Mr. R. K. Richardson, Agricultural Department.
Japan :	Dr. Aso, Tohoku University.
	Dr. Shigematsu, Asahi Brewery.
Kenya :	Mr. G. Shimwell, Kitale.
Malaya :	Mr. Lay Teik Gunn, Department of Agriculture.
	Dr. D. Walker, Weed-control.
New Zealand :	Mr. T. F. A. Archer, President, N.Z. Fruitgrowers' Federation, Wellington.
	Mr. W. Benzies, Apple and Pear Board, Nelson.
	Dr. Kathleen M. Curtis, Cawthron Institute.
	Mr. A. Osborne, Wellington.
Nigeria :	Mr. R. A. Bull, Institute for Oil-Palm Research, Benin.
	Mr. W. E. Freeman, Department of Agriculture, Zaria.
Norway :	Mr. Ola Einevoll, Vollebeck.
	Mr. S. Royset, Foroneset.
	Mr. Gotfred Uhlen, Vollebeck.
Nova Scotia :	Mr. R. D. Sutton, Fruitgrowers' Association.
	Mr. F. Waldo Walsh, Deputy Minister of Agriculture.
Pakistan :	Mr. F. Dad Khan, N.W. Frontier Province.
	Mr. A. Q. Hafiz, Lyallpor, Punjab.
	Mr. A. S. Khan Ghouri, Karachi.
	Mr. A. Mannan Khan, N.W. Frontier Province.
	Mr. M. B. Zaman.
Sierra Leone :	Mr. C. T. Piggott, Agricultural Department.
	Mr. C. T. Pyne, Njala.
	Dr. T. E. Tomlinson, Rokupr.
Southern Rhodesia :	Mr. M. A. Cassidy, Umtali.
Sweden :	Rector Goran Palm, Skogsby.
Switzerland :	Dr. Kobel, Wadenswil.
	Dr. H. Roth, Geigy Company, Basle.
Tanganyika :	Mr. G. K. Reakes-Williams, Agricultural Department.

Tasmania :	Mr. K. Brodribb, Fingal.
Trinidad :	Mr. G. Havord, Imperial College of Tropical Agriculture.
U.S.A. :	Professor L. E. Davis, University of California, Davis, California.
	Dr. and Mrs. George Hervey, Geneva, New York.
	Dr. L. J. Klotz, Riverside, California.
	Mr. E. R. Kuck, New Knoxville, Ohio.
	Professor F. C. Steward, Cornell University, New York.
Yugoslavia :	Mr. E. Strmecki.
Zanzibar :	Dr. F. J. Nutman.

Shows and Demonstrations. Exhibits were staged at the following shows :—

Royal Horticultural Society, Chelsea—May 18th–22nd.
Bath & West & Southern Counties Society, Bath—June 3rd–6th.
Three Counties Show, Hereford—June 9th–11th.
The Royal Agricultural Show, Blackpool—July 7th–10th.
Bristol Horticultural Show, Bristol—September 2nd–4th.

Students and Voluntary Workers. It has again been necessary during this year to refuse many applications from postgraduate students, particularly students from overseas, who wished to work for higher degrees at the Station, as bench space is so limited. It is hoped, when the new laboratories are erected, that it will be possible to accept more students for postgraduate research work.

Mr. M. I. Candela Martinez of the Instituto de Edafologia y Fisiologia Vegetal, Madrid, holder of a British Council scholarship, continued his work for a further year under the direction of Dr. Hewitt.

Dr. G. L. Ducet, of the Centre National de Recherches Agronomiques, Versailles, returned for a further period of work with Dr. Hewitt on 8th July.

Mr. R. K. Richardson of Jamaica spent two months from 6th July, working with the Unit of Plant Nutrition, as part of his study leave in this country.

Miss F. L. C. Blackwall, B.Sc. (Hort.) Ext. London, Studley Diploma in Horticulture, holder of a Ministry of Agriculture two-year postgraduate scholarship in Husbandry, commenced work in the Pomology Section on 1st October for the M.Sc. degree of Bristol University.

Mr. J. B. Howell, a nominee of Somerset County Council, was awarded the Memorial Studentship in Cider-making as from 1st October for six months.

Mr. S. T. C. Wright, Boots' Scholar since 1951, completed his work on 31st December, after being granted by the A.R.C. a four-months' extension to his two-year tenure of the Boots' Scholarship.

Mr. J. M. Rayner, B.Sc., succeeds him as Boots' Scholar for two years from 1st September, 1953, and is working on an entomological problem under the guidance of Dr. Kearns.

The following courses were given in the Domestic Food Preservation Section :—

Preservation of Fruit and Vegetables—August 17th–28th ; August 31st–September 11th.

The usual July course was omitted owing to the Jubilee Celebrations.

Social Activities. The Welfare Committee, under the Chairmanship of Mr. N. G. Morgan for a second year, was responsible for the arrangements for the Jubilee Staff Party at the Station on Saturday, 25th July. In spite of inclement weather the occasion was much enjoyed by the staff and their families. Sports were organised for children and adults, and an opportunity was provided for guests to see over the laboratories and greenhouses during the afternoon. The Welfare Committee also organised the Christmas Party

held in the Village Hall on December 22nd, when the staff produced a pantomime entitled " Apple Antics or Pips in the Pomace," written by Mr. Greenwood and based upon the history of the Station and its Jubilee.

The Football Club, which was formed last year, completed its fixtures for the 1952–53 season in the local Church of England League, finishing tenth in a division of fifteen teams. Of the 26 games played, 7 were won, 4 drawn and 15 lost. The club is continuing in the same league for the 1953–54 season.

The Cricket Club was re-formed during the 1953 season under a new committee : ten matches were played, four won and six lost.

The Men's Tennis Team won eight of the ten matches played in the Bristol & District League, and were again promoted to a higher division for the second year running. The surface of the hard court was relaid by Messrs. En-Tout-Cas in March 1953, and was in a more satisfactory condition for play during the 1953 season.

Acknowledgments. We should like to record our grateful acknowledgments to those members of staff who have served the Station during the year by carrying out special duties in addition to their normal work. Dr. Kearns' assistance has again been most valuable in the planning of new buildings and the organising and supervising of the workshops, including repair work to equipment, machinery and tools for the laboratories and farm. Mr. Spinks has continued to act as Librarian. Mr. Morgan has served for a second year as Chairman of the Welfare Committee, and has thus been responsible not only for the usual Christmas Party but also for the staff celebrations of the Jubilee in the summer. Miss Sturdy relinquished the office of Chairman of the Canteen Committee in November after giving most valuable service in that capacity for three years. Mrs. Pope was elected to succeed her, and, together with Miss Locke and Miss Johnstone, undertook the arrangements for Christmas Dinner on December 23rd, an occasion which was greatly enjoyed.

We are very grateful to these and to other members of staff who have helped in various ways during the year, and to the Assistant and Technical staffs and all other employees for their loyal support in carrying out the programme of research work.

We should also like to thank all our friends outside the Station, particularly growers and commercial firms, for their help and co-operation in our work during the year.

JUBILEE CELEBRATIONS.

By M. GREENWOOD.

The Jubilee of the Research Station was commemorated on July 22nd and 23rd, when celebrations were held jointly by the National Fruit and Cider Institute and the University of Bristol.

On the first day Members of the Institute held their Annual General Meeting in the University and, after lunch in the Refectory, attended the Jubilee Lecture in the Reception Room. In the evening the Governors of the Institute and distinguished guests taking part in the celebrations were entertained by the University to dinner in the Great Hall.

On the second day Members of the University Council, Senate and Staff were amongst the many guests of the Institute who attended a Field Day at the Research Station.

Jubilee Lecture.

The Jubilee Lecture, " Agricultural Research, 1953,"* was given by **The Rt. Hon. Lord Rothschild, G.M., Ph.D., Sc.D., F.R.S.,** Chairman of the Agricultural Research Council, at 3.0 p.m. on July 22nd in the Reception Room of the University ; the Vice-Chancellor, Sir Philip Morris, presided.

In discussing the future of agricultural research in Britain Lord Rothschild stressed the need to survey the short-term problems in agriculture and to study them in the order demanded by their economic importance. He said that in long-term, or academic, problems the Agricultural Research Council was being admirably served by the many gifted scientists whose services it had enlisted ; he wondered, however, whether it might not be possible to attract scientists not quite so gifted to research into the *ad hoc* problems waiting solution rather than to recondite research with no foreseeable application.

As defects in the present organisation of research Lord Rothschild cited the delays attendant on the need for projects to be approved by a succession of committees ; he viewed the present-day cult of committees as a virulent disease for which he had coined the name " boulitis." He regretted, too, that on paper there was no direct contact between the research institutes and the farmer ; he knew this regulation was often broken, and for his part he believed that the closest contact should be encouraged if misconceptions were to be avoided.

Amongst the recent benefits that research had brought to agriculture Lord Rothschild mentioned the improvement in pastures, in grass conservation and utilisation, that had resulted from the combined operations of Rothamsted, Aberystwyth, the Grassland Research Institute, Jealott's Hill, the Hannah Research Institute and the National Institute for Research in Dairying ; the success of the Moredun Institute in developing treatments for the diseases of stock, and the work of the National Institute for Research in Dairying on bacteriophage control in cheese. He estimated that during the past ten years the yields of British cereals had been increased by 5 per cent. as a result of

*Lord Rothschild's lecture is reproduced in full in the Jubilee Volume, " Science and Fruit."

the introduction of selective weed-killers, for whose discovery he thought that British workers at Imperial Chemical Industries and Rothamsted were entitled to at least two-thirds of the credit.

Lord Rothschild referred appreciatively to the work of Professor Wallace and his associates with trace-elements, without which he was certain that both Great Britain and the world in general would be producing far less food. He described Long Ashton as a happy and productive family and said that although fifty years might seem a long time in the life of a man he hoped and believed it would be only a short chapter in the life of the Research Station.

Jubilee Dinner.

Two hundred guests of the University were present at a commemorative dinner in the Great Hall on July 22nd. Toasts were drunk to :—

" The City and County of Bristol " :
Proposed by Sir Robert Sinclair, Pro-Chancellor of the University.
Response by The Right Hon. The Lord Mayor of Bristol, Alderman Kenneth Brown.

" The Guests " :
Proposed by Sir Reginald Verdon Smith, Chairman of the University Council.
Response by The Right Hon. The Earl Waldegrave, Trustee of the Bath and West Society.

" The University " :
Proposed by Sir William Slater, Secretary of the Agricultural Research Council.
Response by Sir Philip Morris, Vice-Chancellor of the University.

Field Day: Long Ashton.

There was an attendance of over 900 at the Field Day at the Research Station on July 23rd. Invitations had been issued by the National Fruit and Cider Institute and the various ceremonies were presided over by **Captain D. M. Wills, C.B.E.,** Chairman and Treasurer of the Institute and Chairman of the Agricultural Committee of the University of Bristol.

Except for a brief period in the afternoon when rain threatened the weather was very kind. The arrangements necessary for the reception of guests and for conducting parties to exhibits and around the plantations were undertaken by the Station staff. A sandwich lunch was served in the marquee between 1 and 2 p.m. and tea at 4 p.m.

Exhibits and Demonstrations.

All the laboratories were open for inspection. Major exhibits were staged as follows :—

Cider House.

Pomology : Spur pruning of apples compared with renewal pruning. Recommended cider varieties.

Plant Breeding :	New varieties of apples, pears, plums and blackcurrants bred at Long Ashton.
Cider and Fruit Juices :	Chemistry and microbiology of cider making. The development of blackcurrant syrup manufacture.
Fruit-tree Nutrition :	Diagnosis and symptoms of deficiencies of potassium, magnesium, copper and zinc. Biological soil tests for mineral deficiencies.
Plant Pathology :	Materials and methods for apple pest and disease control, 1903-1953.

Domestic Food Preservation Building.

Food preservation 50 years ago and today. Demonstrations of modern methods of bottling, canning and freezing.

Plant Nutrition Greenhouse.

Sand culture methods. Demonstrations in vegetables and cereal crops of the effects of deficiencies of all the known essential mineral elements.

Adjoining the Biology Building.

Willow growing : the utilisation of osiers in basket-making. Cricket bat manufacture.

Library.

Publications by past and present members of the Department of Agriculture and Horticulture.

Plantation Tours.

Three tours, each estimated to last one hour, started at intervals from the Cider House. The first tour was scheduled to start at 11 a.m., but an advance party was made up by 25 members of East Malling Research Station who had paid us the compliment of travelling overnight from Kent by motor coach.

Tour A : Plant Nutrition.

Effects of long-term manurial treatments on growth of strawberries and apples (Plots 12 and 15). Effects of manurial treatments on growth and yields of potato and cauliflower (Plot 17A).

Tour B : Apple Tree Spacing. Spraying Equipment.

Establishment and management of dessert apple trees under different systems of planting, spacing and shaping (Plot 24). Spraying equipment for fruit : automatic and small-volume sprayers (Machinery Sheds).

Tour C : Cider-Orcharding. Growth-regulating Substances.

Bush cider-trees established in 1936. Grass and arable systems (Plot 20). Use of growth substances for apple thinning and for accelerating ripening (Plot 14).

Tree-Planting Ceremony: 2.15 p.m.

Emeritus Professor B. T. P. Barker, C.B.E., M.A., Hon. F.R.H.S., has been associated with the Research Station since its inception : as Assistant Director (1903–05), as the first resident Director (1906–43), as part-time worker in the Cider Section (1943–50) and latterly as guest research-worker. It was

fitting that as a memorial to his 50 years of service to the cider industry he should be asked to plant a cider apple-tree near the orchard he had established fifty years previously. It was doubly fitting that the variety should be Ashton Brown Jersey, as it was found growing on the farm when it was acquired by the Institute and was later proved of sufficient merit to be included amongst the varieties recommended for general planting.

Present at the ceremony was Mr. Martin Chart who, as a member of the Institute staff between 1903 and 1907, had planted the original orchard. A Press photograph taken during the occasion offers a fair expectancy of longevity to those who think of making a career in agriculture : besides Professor Barker (75) and Mr. Chart (81) it includes Lord Bledisloe (85) and Sir John Russell (80). Few, seeing Professor Barker's bronzed countenance, can have feared that he would fail to accept Captain Wills's invitation to return and assess the vintage quality of the tree he had planted.

Unveiling of Plaque : 2.30 p.m.

The association between the Bath and West and Southern Counties Society and the Research Station is ante-natal, for the Society had supported Neville Grenville in the experiments whose success led to the Institute's creation. The Society not only provided a large part of the Institute's original income : its members were always at hand to help it through the many difficulties it encountered in its early life. This help has continued through the succeeding years, during which representatives of the Society have given generous service on the governing body of the Institute and on the Agricultural Committee of the University.

The Research Station has been proud of this long connection and was gratified to learn that the Society wished it be recorded by the presentation of a handsome lacquered brass plaque bearing the inscription :—

> *This tablet commemorates the part played by the Bath and West and Southern Counties Society in the establishment of the National Fruit and Cider Institute in* 1903 *and the close collaboration between the Society and the Institute in the succeeding years.*
>
> *Presented by the Bath and West and Southern Counties Society at the Jubilee Celebrations* 23 *July*, 1953.

The plaque was unveiled in the Library by **The Right Hon. the Viscount Bledisloe, P.C., G.C.M.G., K.B.E.,** Senior Vice-President and a past-President of the Society. Viscount Bledisloe's association with the Station has been an exceptionally intimate one : he was Chairman of the Governors of the Institute between 1920 and 1922 and Chairman of the Agricultural Committee between 1920 and 1925.

He said :—

" It is not unfitting that at a conspicuous landmark in its career a great National Institution, like human beings, should, in the words of the book Ecclesiasticus, praise its famous men and the father which begat it, while not unmindful perhaps of a foster mother who cherished it in its infancy. This little ceremony may serve as a friendly reminder of past happenings ' pregnant ' in important developments of high economic value.

Many of us West Countrymen can remember with no great pride the old farm and estate cider mill, in which revolving stone rollers, operated by the roundabout activities of an old

cart-horse, expressed an often murky juice from dirty apples, which had picked up ferments of animal origin while lying on the ground in lichen-infested orchards.

In 1893 (60 years ago) Robert Neville Grenville (the Squire of Butleigh) initiated on his property research into the manufacture of cider, rebelling against the crude and dirty methods then universally employed in the process. He, in fact, did at Butleigh for the only true wine of England what another English squire—my old friend, John Bennet Lawes—did at Rothamsted for British agriculture. He was aided in the task by the late Mr. F. J. Lloyd, F.C.S. The work was duly recorded annually in the Journal of the Bath & West Society, and eventually published by the Board of Agriculture. It was financed by the Society and also by the Board.

In July, 1902, under the influence of Mr. Grenville and of Mr. Lloyd, and with a growing recognition of the great importance and value of this Butleigh research, a meeting of those chiefly interested was held, at which the need for wider scientific research was emphasised, and it was agreed that the Board of Agriculture should take the lead in the matter. This it was quite willing to do, and it invited the Bath and West Society and the West-Country County Councils to co-operate. The result was the decision to establish a fixed Cider Institute, centrally situated, which should occupy in regard to the Cider Industry a similar position to that occupied by the fixed Cheese and Butter-making schools in regard to the Dairy Industry. It was also suggested that possibly the new Institute might include in its ambit instruction in fruit growing and fruit utilisation, in addition to the making of cider and perry.

This was followed by a Conference which was held at Bristol on 15th October, 1902, presided over by Sir Thomas Elliott, then Permanent Secretary of the Board, and attended by representatives of the Bath and West Society and of the Counties of Somerset, Gloucester, Worcester, Hereford, Monmouth, Brecon, Dorset and Cornwall. At it a resolution was unanimously adopted that such an Institute should be established in the West of England. A representative Committee was nominated to report to the Board, Mr. Neville Grenville being the representative of the Bath and West Society. After inspection of several different sites, the one mainly favoured was that on which we are now assembled, forming part of the Ashton Court estate of the late Lady Smyth, who was willing to place it at the Committee's disposal. On the 28th May, 1903, at the Bath and West Show at Bristol, a conference was held of leading cider enthusiasts and the scheme was cordially approved, the Bath and West Society undertaking to subscribe £100 annually, and other subscriptions being promised by the Board of Agriculture and the County Councils.

One of the conditions of the scheme was that the Annual Meeting of the Institute should be held in the show ground of the Bath and West, and that any exhibits that the Institute desired to provide should be displayed at the Show. The Society was to be at liberty to publish any reports emanating from the Institute, and the Reports of the Institute's work appeared regularly in the Society's Journal from that day until the last issue of the Journal in 1939. The Institute has exhibited regularly at the Bath and West Shows, and is in fact still doing so. Under the terms of the Institute's constitution and in view of its annual subscription, the Society nominates two of the Governors of the Institute.

The relations between the Society and the National Fruit and Cider Institute have always been of the most intimate and cordial character.

On such an occasion as this we cannot forget our old friend, Professor B. T. P. Barker, who for 37 years out of the last 50 years was Director of the Institute after being previously for two years the Assistant Director.

I was, myself, Chairman of the Governing Body of the Institute 30 years ago, succeeding in that post my much respected friend, the Right Honourable Henry Hobhouse. The Society for which I speak today and of which I am the oldest surviving past President, although not the originator of this now famous National Research Station, is at least its proud foster parent, and this plaque is intended as a permanent memorial of our close relationship with it since its birth and during its remarkably successful development. Thanks to its scientific and research activities, the cider of England has improved in quality and wholesomeness by at least 100 per cent. during the last half century, and I venture to believe that the health of those who are wise enough to drink it has shown commensurate benefit. I cannot resist mentioning that an elder statesman and ex-Cabinet Minister who, although over 80, displays the most brilliant intellect in the House of Lords today, confessed to me a few months ago that he attributes his extraordinary physical and mental vigour to making cider his sole beverage.

In conclusion may I express the hope that, although the activities of Long Ashton Research Station, with a notable change in its original title, have in recent years expanded amazingly into such fields of research as plant breeding, the control of pests, the cultivation of willows, the domestic preservation of vegetables, Vitamin C juices, and the fascinating subject of trace elements, those connected with it will never forget that it owes its existence to the invigorating "Apfelwein" of England, to an enlightened and far-sighted Somerset county squire, and in no small measure to the Bath and West Society, of which he was a prominent member and which backed him enthusiastically from the start.

The Society, after half-a-century of friendly partnership, tenders to you, Professor Wallace, and your Governors and colleagues, its warmest congratulations on your Research Station's Jubilee, and its cordial good wishes for continued prosperity and usefulness to the horticultural and agricultural industries."

Speeches: 3 p.m.

Some perturbation had been felt when it was learned that the Minister of Agriculture and Fisheries, **The Rt. Hon. Sir Thomas Dugdale, Bart.,** who had generously accepted the invitation to be guest speaker, had been summoned to an emergency Cabinet meeting that was expected to be in session at a time when he should have been well on his way to Long Ashton. Thanks to the resource of the Vice-Chancellor and to the kindness of Sir Reginald Verdon Smith and the Bristol Aeroplane Company, arrangements were made to fly the Minister from Hendon in a Bristol helicopter. This arrangement was known to few beside the farmer in whose field permission to land had been sought, and the Minister's audience was dutifully seated on the lawn when he and Sir Reginald passed (or " clattered," as an old fruitgrower-journalist friend of the Station has described it) within bowshot overhead. The Minister was not slow to refer to his novel method of descent and said :—

" First I must thank the Agricultural Committee of the University Council and the National Fruit and Cider Institute for inviting me here today. I am delighted to be with you for these Jubilee Celebrations, and I am only sorry that my stay with you has had to be such a short one. Completely unforeseen circumstances have made my visit, in the most literal sense, " a flying one." But for the resource and kindness of your Vice-Chancellor and the Chairman of the University Council I doubt whether I should have been able to—how shall I put it—drop in on you today.

Your Station at Long Ashton is a very good example of the varied way in which our research arrangements in Great Britain have grown up and the varied forms they take. You have only to look at the recent booklet by the Agricultural Research Council to be aware of this. There has been no set plan imposed from above—the institutions have grown out of an effort to meet definite needs, to solve definite problems. In their establishment and development all kinds of persons and bodies have co-operated —private individuals with an itch to discover and the means to indulge it ; learned and academic bodies ; commercial firms and associations of producers, and local authorities, and of course the Government.

It was 60 years ago, in 1893, that Mr. Neville Grenville, a Somerset landowner, decided that farmhouse cider was not what it ought to be. I believe he thought it a bit too " rough " for the uneducated palate of the townsman. Ten years later, in 1903, it was he who was the prime mover in setting up the National Fruit and Cider Institute. From the start his plan had the support of the Bath and West and Southern Counties Society, of prominent horticulturists and cider makers and of the County Councils of the cider-making counties. The Board of Agriculture, knowing a good thing, was also in at the start. Big developments in agricultural research and education followed. In 1912 the Institute became associated with Bristol University ; it acquired new funds for research from the Development Commission, and became the advisory centre for the South-West. Since then your Station has never looked back—except at anniversaries. Its work has widened and deepened, it has received increasing support from my Department, and it has, since 1931, come into the ambit of the Agricultural Research Council's arrangements. It has been a case of all pulling together and therein, I suggest, has lain the strength of your Station, and of similar Stations elsewhere.

Long Ashton is primarily a horticultural research station and research has a vital part to play in making our production more efficient, whether it is cereals or cider, plums or pigs.

I have been most interested to learn of the variety of the work which the scientists at Long Ashton are undertaking, and I must congratulate Professor Wallace and Mr. Marsh on their excellent book about it. The interest of your founding father, Mr. Neville Grenville, in the apple has yielded a rich crop of scientific discoveries. I doubt whether the earlier interest of that great scientist—Sir Isaac Newton—in the same fruit ever yielded a richer one. You have maintained your research on cider and fruit juices ; but you also have your fundamental studies of the fruit tree ; your newer work on the control of the hordes of pests and diseases that attack our fruit ; and your remarkable work on plant nutrition. In these studies the name of Long Ashton is a household word wherever fruit can be grown in the world. I am glad to see that your work on the willow continues to flourish. In my county we—at least until this season—have known how to use its product, weather permitting. The Station has also done excellent work on the home front in the preservation of fruit and vegetables. This is all continuing and is being extended to meat. I am sure that all Women's Institutes will look forward to getting some really sound advice.

I know that all these activities taken together have given Long Ashton a secure place in the regard of all connected with agricultural and horticultural improvement throughout the country, and indeed throughout the world, but especially in the West Country, with whose

farmers and growers the Station has had so many contacts. The advent of the N.A.A.S. has inevitably meant less direct communication between the Station and the counties, but plenty of opportunities for contact remain and the friendliest relations persist between the Station and the Service.

We all know that work like this does not perform itself—it is done by people, whose loyal service over the years gives an institution like this a soul of its own. In the fifty years of Long Ashton's life many have laboured here fruitfully (I hope the word is permissible), and I am sure that you will agree that they, like others who laboured in an earlier horticultural establishment, have been more than worthy of their hire.

The Station has been fortunate in its Directors—Professor Barker whose forty years service spanned the life of the Institute from its very beginning until the middle of the late war. What a splendid record of achievement and how glad you will all be to see Professor Barker with us today! Now you have another Director of great distinction in Professor Wallace. His work on plant nutrition alone has brought him world renown and he is in every way maintaining the reputation of the Station. We at the Ministry were delighted to hear of his election to the Fellowship of the Royal Society this year; and I should like to take this opportunity of thanking him for the enormous amount of help he has given us in the horticultural work of the Agricultural Improvement Council and in the preparation of our horticultural bulletins and leaflets. I am glad to say that he has recently accepted my invitation to become a member of this Council.

Now what of the future? I have no doubt at all that Long Ashton is going to carry on in the true scientific spirit. The Station can be assured of the support of my Department and the Agricultural Research Council and the esteem of the horticulturist. One problem which I know exercises the Station is its physical facilities. Work grows, staff grows and buildings get crowded. I know that the Committee of Management and the Director would like to see new glasshouses, and that they have projects for more laboratories and other appurtenances of an up-to-date Station.

Just because I descended from the clouds today I hope you will not imagine that I am a *deus ex machina* who can work miracles. As I am sure you know, we Ministers are only human, and it is as humans that we have to keep the balance between the many claims on our limited capital resources in the agricultural research field alone, not to speak of others. There is so much that is desirable that it will take time to work it all out. But we are always ready to look sympathetically at a Station's essential needs. I know, for example, how anxious Long Ashton is to get some new glasshouses and I am hopeful that you will be able to see this work in hand next year.

May I as Minister for the industry for the benefit of which the Station does its work, say how much that work is valued."

The Minister was followed by **Mr. C. P. Norbury,** Vice-Chairman of the National Fruit and Cider Institute and a member of the Agricultural Committee of the University.

Mr. Norbury said :—

It is a great honour to be associated with these Jubilee Celebrations. Since 1940 I have been on the Finance and Business Committee of Long Ashton, having succeeded my father, the late F. P. Norbury, who for many years served on this Committee. He first became associated with Long Ashton Research Station in 1910 when he planted out on his farm one of the trial orchards of so-called dual purpose apples. In those days the two main purposes of an apple were for cooking and for cider making.

As a fruit grower I look upon Long Ashton Research Station as one of the foundation stones upon which we build our industry. No progressive grower doubts the value of research and its value is recognised more and more by the nation as a whole. Unfortunately it has not always been so. Many times I remember my father returning home from Long Ashton, wondering whether there would be enough money to carry out the research programme, and it was a great worry for those on the Committee, and particularly the Director of the time, to know how they were going to make both ends meet. The recent publication on the Agricultural Research Stations, to which the Minister has just referred, is an indication of the great progress that has been made since those days.

From the purely financial aspect, the money that has been invested in Long Ashton has paid enormous dividends. The work has contributed not a little to the establishment of the fruit industry in the United Kingdom—so much so that the home grower can now fill the market with dessert apples until at least the first week of December, and with cooking apples for very nearly all the year round. Production per acre of apples, pears, cherries and plums has increased enormously—and not only have we got this increased production per acre, but in recent years there is far greater regularity of cropping, which is so essential to get even supplies to the home market, and which is basic to any organised marketing of the home crop. If one compares the price of fruit in the shops today with pre-war, it will be seen that fruit has gone up less than many other commodities, and this has been due largely to the increased production per acre

and the increased production per man. These increases have enabled the fruit industry to carry on—without them it would indeed be in a precarious position.

The far greater knowledge of the use of insecticides and fungicides and the greater understanding of the manurial requirements of our fruit trees, subjects largely developed at Long Ashton, have been a tremendous source of strength to our industry. Unfortunately the increased yields brought about by practising the methods evolved at the Research Station are bringing new problems. In the case of plums difficult problems in disposal have already arisen, dating from the introduction of tar-oil wash. With apples similar problems may also arise.

Long Ashton has not only carried out much fundamental research on cider, but has also studied the problems of unfermented apple juice and unfermented blackcurrant juice. The latter led to the establishment of a new industry which, during the war, was absolutely essential to the proper nutrition and welfare of our children, and which in peace time has increased the consumption of blackcurrants, with their high Vitamin C content, to the benefit alike of the nation and the fruit grower. Further research on fruit products will, I feel sure, go a long way towards finding new outlets for fruit. I am delighted to know that the Minister feels the same, that the research programme on fruit products should not only continue, but should be developed even more.

Looking back I can well remember the scourge of leaf scorch in the 1920's. We had trees on our own farm which were so potash-starved that they were rotting away in the ground; we thought the cause was moles or voles. They were about to be pulled up when Professor Wallace came along and told us what was needed was potash—and today these trees are carrying full crops. It was not until Long Ashton studied the manurial and spraying requirements of the Cox's Orange Pippin and recommended how it should be grown that growers were given sufficient confidence to plant it out on a large scale. Up till about 1928 growers were extremely nervous of planting Cox because they had only one good crop every three years or so. It is now our leading commercial dessert apple.

One cannot allow this occasion to pass without recognising how large a part the University of Bristol has played in the development not only of Long Ashton but also of the Campden Research Station, which has been so vital to the fruit growing industry.

There is not time to deal with the many aspects of work carried out at Long Ashton, such as fruit breeding, from which several new varieties are likely to be of great benefit, and the development of insecticides and fungicides, particularly of their use and mode of application, which are continually changing. It is of the utmost importance that new products in these fields should be tested under conditions such as a University can provide, so that their value, and the problems attaching to their use, may be critically assessed without fear of bias of any sort.

Long Ashton is also the Research Station for investigating problems of domestic food preservation, which subject now includes not only fruit and vegetables, but meat and poultry also. This work is of great value to Women's Organisations throughout the country, and here again completely unbiased advice is essential.

Before summing up I should like to say that in recent years there have been great improvements in the organisation and working of the research and advisory services. It was always a criticism in the past that the work that was done was not always readily available to the general body of farmers and growers. Since the setting up of the N.A.A.S. this criticism is no longer valid. The N.A.A.S. has contacts both with the Research Stations and with growers, and the research workers have now much more time to give to their own work. May I stress the importance of increasing still further the liaison between advisers and research workers? I look forward to the time when an adviser can walk on to any farm, without previous notice—and get a welcome from the farmer or grower as a trusted friend. The second great improvement is that, owing to the realisation that agricultural research is so vital for our survival as a nation, there is far greater willingness by the Government to see that research is developed and means provided to carry it out.

I feel that this country is in very much the same position as a farmer who is short of money—there are certain things on his farm that can be neglected for a year or two, maybe roads and hedges, but the things that must never be neglected are the fertilizers and the cultivations. As a farmer, I hope the Government will regard the grants made to the research station as being as important as the use of fertilizer on the farm, and the Director and his staff as the cultivators upon whom all success must ultimately depend. May the combination long continue to produce rich harvests."

In thanking the guests for their presence the Director of the Research Station, **Professor T. Wallace, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.,** said :—

"My first duty in addressing you today is a very pleasant one. On behalf of the Agricultural Committee of the University, the Governors and Members of the N.F.C.I. and the Staff of the Station, I wish to thank you all for your presence. It has indeed been very gratifying to us that so many friends should have come here today to take part in these celebrations.

Sir Reginald Verdon Smith will be proposing a vote of thanks to the Minister of Agriculture, but I know he will not mind if at this stage I express my personal thanks to the Minister : he has overcome great difficulties to be with us, and our best thanks are due to him both for his presence and his gracious speech. We have been profoundly heartened by his kind references to the value of our work to the Ministry and to the farming industry.

I should like to thank the Council of the Bath and West Society for the beautiful plaque they have presented to us. It will always serve as a reminder of the part the Society played in the establishment and early development of the N.F.C.I. and of the members of the Society who did so much for us in those early days ; it will also remind us of our continuous and active collaboration since 1903. In this connection, in addition to Mr. Neville Grenville I would recall the part played by Mr. H. B. Napier, Treasurer of the Society, and also of the Station throughout its early difficult years, who, as Agent to the Ashton Court Estate, procured for the Institute the present site. It is our hope that the Society may feel a little pride in its offspring after the first fifty years of its work and development. We, for our part, are proud of our illustrious parent.

Today a very distinguished member of the Society presented the plaque to us—a man whose services to agriculture over the years have been very great—I refer to Lord Bledisloe. The Station is proud to claim him as a past Chairman and as one who has made the name of Long Ashton known far beyond the shores of Britain. I suspect he is here today against his doctor's orders, but I know this is a great occasion for him ; we rejoice that he is with us and we thank him for his presence.

It is also a pleasure to see that Sir Charles Miles is here to represent the Bath and West on this occasion : he is one of our very old friends, who has long carried on the traditions of the Society in regard to agricultural research and education ; I myself have been actively associated in that work for more than thirty years, and I know something of his great contribution.

There are many other particular friends whom we welcome and would thank for joining in our celebrations today :—Sir John and Lady Russell ; Sir Donald and Lady Vandepeer ; Sir Alan Hitchman ; Sir James Scott Watson and Sir Reginald Franklin from the Ministry of Agriculture ; and Sir William Slater, Secretary of the Agricultural Research Council.

We have Dr. T. Loveday, for many years Vice-Chancellor of the University and Chairman of the Agricultural Committee. To him the Station owes much for its successful development between the two great wars. We still regard him as one of the family. Then we have with us Dr. H. V. Taylor who, whilst at the Ministry of Agriculture, for many years gave us valuable help and counsel as a member of our Committee and who, as a Somerset man, we know to have always a particular affection for Long Ashton.

We are also delighted to welcome representatives of the Royal Agricultural Society, the Chairman of the Central Horticultural Committee of the N.F.U., Mr. Eric Gardener, and the Chairman of the Farmers' Club, Sir William Gavin. The presence of these representatives of these great farming organisations is very gratifying.

We are also privileged to have with us today several members of Commonwealth Governments—from Canada, New Zealand, Australia, the Union of South Africa and Pakistan. It has been a very great pleasure to welcome these friends from overseas, with whose countries we have established many contacts in our work. Then we also have the Agricultural Attaché of the Netherlands Government, Dr. de Bakker. No horticultural gathering in this country would be complete without a representative of that great country of horticulturists. We have also received a large number of messages of greeting from others of our overseas friends who have been unable to be with us today.*

Long Ashton has always had many friends among growers, cider-makers and business firms, and has enjoyed close collaboration with them in its work over many years. Many representatives of these various interests are here today, and I should like to thank them all for their past help and for their support in our Jubilee Celebrations.

Then, if I may turn to what I may term 'the family'—our sister Universities and research stations and the agricultural colleges. Here we have representatives not only from England, from Scotland, Wales and Northern Ireland, but also from New Zealand and the U.S.A. Our closest relatives among the research stations are, of course, East Malling and The John Innes, who are represented by Mr. T. Neame and Dr. F. R. Tubbs (East Malling) and Mr. M. B. Crane (John Innes).

*The many congratulatory messages, to which Professor Wallace referred, included one from the Instituto de Edafologia of the Consejo Superior de Investigaciones Cientificas, Madrid. This consisted of an address in Latin verse engrossed on vellum. The translation reads:—

IN THE JUBILEE YEAR.

With happy omens go rejoicing on your way unceasingly.
But for a moment halt your steps while we, your friends, rejoice.
Your Director's brilliant words have shone forth here.
We share your pleasure in his work with you.
Everything happily unites our hearts.
May this happy fellowship of ours endure and never fail.

I am sure that, as members of a well brought up family, the representatives of the other stations and colleges will forgive me if I do not refer to them by name. Our thanks for their presence are none the less warm.

Any speech by a member of the Long Ashton staff on this Jubilee Day would be incomplete without some reference to Professor Barker, 'the young graduate' of 1903 from Cambridge University, for this is also his Jubilee. We might describe him as 'fifty years young' today, for surely he is one of those who refuse to grow old. He has celebrated his Jubilee year by planting a Jubilee cider apple tree of Ashton Brown Jersey. I can think of nothing more appropriate for the occasion, and we all wish that he may long be with us to watch its growth and see it bear fruit—and, may I add, to judge its vintage quality.

And now may I say just a few words about the Jubilee itself. It means, of course, that the Station is now 50 years old, and has behind it fifty years of work and, I hope, of achievement. We have tried to summarise some of its main contributions both to science and to practice in our Jubilee Volume, and I must leave the book to tell our story. We feel that over the fifty years we have built up a tradition in our work to guide us in the future.

We have now a large staff of well-trained scientists, with equipment and facilities undreamed of fifty years ago and which improve yearly. Surely we may then look forward with confidence to the next fifty-year period as one of progress undreamed of not only by those who founded the Institute but also by those who are present here today.

In conclusion, may I quote from a passage in the Jubilee Volume. It is a slightly modified version of a statement in an article written by Mr. Brooke-Hunt of the Board of Agriculture in 1903, describing the establishment of the National Fruit and Cider Institute :—

> 'It began, as most things do which really last, in only a small way, and it has developed naturally in accordance with the needs of the times; its spirit remains young and the potentialities are great; it is hoped that its career may continue to be one of increasing usefulness, not only to this generation, but to others which are to follow.'

May I, once more, thank you all for your presence here today, and the Minister and Mr. Norbury for their kind references to the Station's work."

Jubilee Volume.

Coincident with the celebrations the University published a Jubilee Volume to serve as a record of the activities of the Station during the first fifty years of its life.

The contents of this volume, "Science and Fruit,"* are shown below. There are a number of special articles, written by past and present members of Station staff : some give a general account of the more important subjects to which the Station has made substantial contributions over a period of years ; others summarize developments in the major subjects at present under investigation. An account is also given of the events leading to the establishment of the National Fruit and Cider Institute and of its subsequent development ; the story is well illustrated by a series of photographs which includes a portrait of Mr. R. Neville Grenville whose pioneer experiments in cider-making led to the establishment of the Institute.

The volume contains the Jubilee Lecture by Lord Rothschild, a preface by the Station's Chairman, Capt. D. M. Wills, and a signed foreword contributed by the Chancellor of the University, Sir Winston Churchill.

Thanks to the generosity of a number of the Station's friends it was possible to print 2,000 copies of the volume and to make an unusually wide distribution to libraries of scientific institutions. The volume has been reviewed most favourably, and many kind things have been said of the authors, the editors and the printers. A new demeanour has been apparent in members of the Cider Section since one well-known journal headed its review "Priests of Pomona."

* '*Science and Fruit.*' Edited by T. Wallace and R. W. Marsh. University of Bristol, 1953. Pp. 308, plates 31. Price 30s.

CONTENTS.

Frontispiece - R. Neville Grenville, J.P.

Foreword - By The Right Honourable Sir Winston S. Churchill, K.G., O.M., P.C., C.H., LL.D., F.R.S., M.P., Chancellor of the University of Bristol.

Preface - By Captain D. M. Wills, C.B.E., Chairman of the Agricultural Committee of the University of Bristol and of the Governors of the National Fruit and Cider Institute.

The Jubilee Lecture - Agricultural Research, 1953 - By The Right Honourable Lord Rothschild, G.M., Sc.D., Ph.D., F.R.S., Chairman of the Agricultural Research Council.

Introduction:— AUTHORS

Long Ashton Research Station : its origin and development *T. Wallace and B. T. P. Barker*

Cider and Fruit Juices:—

Cider and cider-making fifty years ago .. .. *B. T. P. Barker*
Cider apple varieties then and now : a survey of vintage quality trials *B. T. P. Barker and L. F. Burroughs*
Factors affecting the quality of cider .. .. *A. Pollard*
Disorders of cider .. .. *F. W. Beech and J. G. Carr*
Developments in fruit products .. .. *V. L. S. Charley and A. Pollard*

Fruit Culture:—

Factors governing fruit bud formation .. .. .. *T. Swarbrick and L. C. Luckwill*
Plant hormone research at Long Ashton .. .. *L. C. Luckwill*
Some aspects of blackcurrant culture .. .. *C. Bould, E. W. Hobbis, H. G. H. Kearns and R. W. Marsh*
Surveys of fruit soils .. .. *D. A. Osmond*
Some effects of orchard factors on the quality and storage properties of apples *T. Wallace*
Fruit breeding at Long Ashton .. .. *G. T. Spinks*

Plant Nutrition:—

Sand culture methods in plant nutrition studies .. .. *E. J. Hewitt*
The mineral nutrition of fungi with special reference to *Aspergillus niger* and *Penicillium glaucum* .. .. *D. J. D. Nicholas*
Chromatography in the study of biochemistry and nutrition of plants .. *A. H. Williams*

Plant Pathology:—

Important pests of fruit, 1920-1950 .. .. *H. G. H. Kearns*
Apple and pear scab .. .. *R. W. Marsh*
Insecticides and fungicides in fifty years of fruit culture .. .. .. *J. T. Martin*
The chemical standardisation of insecticides and fungicides .. .. *J. T. Martin*
The insecticidal activity of D.D.T. and related compounds .. .. .. *D. Woodcock*
Spraying machinery and spraying methods over fifty years *H. G. H. Kearns and N. G. Morgan*

Domestic Food Preservation:—

Scientific aspects of the domestic preservation of fruit and vegetables .. *Alice Crang*

Chairmen of Committees and Scientific Staff, 1903-1953:—

Governing Body of the National Fruit and Cider Institute.
University Agricultural Committee.
Finance and Business Sub-Committee
Scientific Staff.

Governing Committees, 1953:—

Governors of the National Fruit and Cider Institute.
University Agricultural Committee.
Finance and Business Sub-Committee.

Staff, 1953:—

Scientific Staff.
Assistant Staff.

VIRUS DISEASES OF FRUIT TREES: IV. FURTHER OBSERVATIONS ON RUBBERY WOOD, CHAT-FRUIT AND MOSAIC IN APPLES.

By L. C. LUCKWILL.

A previous article in this series (1) dealt with the origin and mode of spread of these three diseases, with particular reference to the variety Lord Lambourne. The present paper summarises the results of further experiments on this subject carried out during the past four years.

Distribution of rubbery wood virus in clonal rootstocks.

In a previous experiment in which seven different Malling rootstocks were budded with virus-free Lord Lambourne, it was found that the trees worked on M.II were all healthy, whereas a varying proportion of those worked on other stocks showed symptoms of rubbery wood by the end of their second year of growth (1). It was concluded from this experiment that these clonal stocks were acting as symptomless carriers of the rubbery wood virus. This conclusion has since been confirmed in a similar experiment carried out at East Malling (2). Of the stocks tested at Long Ashton M.I. appeared to be the most severely infected, 63% of the trees on this stock being graded as definitely rubbery and a further 28% as suspected rubbery. All the stocks in this experiment came from the Long Ashton stoolbeds, so that it was not possible to say whether this infection was general throughout the country. Neither was it possible, on the results of this experiment alone, to recommend M.II as a " safe " stock for Lord Lambourne, since the absence of infection of this stock in the Long Ashton stoolbeds might well have been fortuitous.

A further experiment was therefore carried out in which samples of M.I and M.II stocks from commercial nurseries and research stations in different parts of the country were tested for rubbery wood virus by budding them with virus-free Lord Lambourne. The stocks, from seven different sources, were planted in the winter of 1949-50. They were budded in 1950 with bud-wood from the " original " Lord Lambourne trees which were known to be free of the virus. The maiden trees were scored for rubbery wood during the winter of 1951, and again as two-year-olds in the winter of 1952. The results of this experiment are shown in Table I.

Two points of particular interest emerge from this experiment. The first is the apparent absence of the virus from all the M.II stocks, irrespective of the source from which obtained. There seems to be no particular reason why this stock alone should have escaped infection and the evidence suggests that M.II may be resistant to rubbery wood in the sense that the virus, although it may be present, is unable to spread and become systemic in the tissues. A further experiment to investigate this possibility is in progress.

The second point of interest is the marked difference in the degree of infection of M.I from different stoolbeds. The samples from sources 4 and 6, both of which were old-established commercial nurseries, proved completely free from infection. Enquiries showed that both these nurseries obtained their original supplies of M.I from East Malling prior to 1930 and that their present

stoolbeds had been derived entirely from this material. Source 5, which showed some infection with rubbery wood, was a stoolbed on a fruit farm established about 15 years ago. By contrast with those from commercial sources the M.I stocks from stoolbeds at Long Ashton (source 1), East Malling (source 2) and the School of Agriculture at Sutton Bonington (source 3) were all heavily infected with rubbery wood virus. During the past 10 years there has been interchange of rootstocks between all of these three centres.

TABLE I.

INCIDENCE OF RUBBERY WOOD VIRUS IN M.I AND M.II ROOTSTOCKS FROM DIFFERENT SOURCES.

Source of stocks	Malling No. I				Malling No. II			
	Total no. of trees	Healthy	Suspected rubbery	Definitely rubbery	Total no. of trees	Healthy	Suspected rubbery	Definitely rubbery
1.	25	0	2	23	24	24	0	0
2.	23	6	5	12	25	25	0	0
3.	21	0	4	17	24	23	1	0
4.	23	23	0	0	21	21	0	0
5.	24	13	5	6	24	23	1	0
6.	23	23	0	0	23	21	2	0
7.	—	—	—	—	22	19	3	0

These observations would seem to indicate that the M.I stock was originally free of rubbery wood and, although it is not possible from these limited data to determine the date when it first became infected, there is a suggestion of a progressive build-up of the virus during the past 20 years. The existence of beds of M.I which are still free of rubbery wood may prove of practical importance, as such beds might provide a useful starting point for the re-establishment of virus-free selections of this stock.

Clonal rootstocks as carriers of chat-fruit.

The indexing of rootstocks for chat-fruit virus is a much more lengthy process than indexing for rubbery wood, owing to the fact that the visible symptoms are confined to the fruit. Thus, whilst it is possible to say at the end of the first year, or at the latest at the end of the second year of growth, whether trees are rubbery or not, it is usually necessary to wait seven or eight years in order to determine whether they are infected with chat-fruit.

In 1945 seven different Malling rootstocks from the Long Ashton stoolbeds were budded with healthy buds of Lord Lambourne, taken from the "original" (1) trees which were known to have remained free of virus for many years. The incidence of rubbery wood in the two-year-old trees was recorded in a previous report (1). It was not possible to grow all these trees on to the fruiting stage, but in 1947 a random selection of 207 trees was

planted out at 6 × 12 ft. for observations on the occurrence of chat-fruit. The trees were lightly pruned to encourage early cropping and observations on fruit size and colour were continued up till 1953, by which time even the trees on the vigorous stocks were cropping freely. The results are presented in Table II.

TABLE II.

INCIDENCE OF CHAT-FRUIT VIRUS IN SEVEN DIFFERENT CLONAL STOCKS FROM THE LONG ASHTON STOOLBEDS, AS DETERMINED BY INDEXING WITH LORD LAMBOURNE.

Stock	No. of trees	Normal	Severely chatted	Moderately chatted
I.	19	19	0	0
II.	27	27	0	0
IV.	32	25	3	4
VII.	37	37	0	0
IX.	33	33	0	0
XII. ..	27	26	1	0
XVI.	32	30	1	1

Of the 207 trees in this experiment 10 (4·8%) showed definite symptoms of chat-fruit. It is possible that these trees became infected from some external source between the time they were budded and the time they started to crop : but excluding this very remote possibility it would appear that certain clonal stocks can and do act as carriers of this virus. The incidence of chat-fruit, however, was very much less than that already recorded for rubbery wood in the same sample of stocks (1). The highest degree of infection was found in M.IV (22%) followed by M.XVI (6%) and M.XII (4%). Stocks I, II, VII and IX appeared to be free of chat-fruit, though all except M.II were highly infected with rubbery wood. These results therefore emphasise the complete independence of these two viruses, which has been commented on in the previous report.

The indexing of rootstocks for latent chat-fruit virus on an extensive scale, using Lord Lambourne as an indicator, is clearly impracticable owing to the time taken for the symptoms to show (at least 7–8 years for vigorous stocks) and the large areas of land required. Such an undertaking, which is undoubtedly highly desirable, will only become practicable if and when a more suitable indexing technique for this virus is discovered.

Tolerance of apple varieties to mosaic.

A number of instances have been recorded of apple trees developing symptoms of mosaic following headworking to another variety, even though the original tree and the scions used for working were apparently free of the disease. Such observations suggest that certain varieties of apple may be capable of acting as symptomless carriers of this virus. In order to test this hypothesis the following experiment was carried out :—

168 maiden trees of virus-free Lord Lambourne growing on seedling stocks were infected in the summer of 1949 with the vein-banding strain of apple mosaic (3) by insertion of a single infection bud carrying the virus in the stem of each tree. The following year all the trees developed very intense mosaic symptoms. In the spring of 1951 they were top-worked with 42 different varieties of apple, each variety being worked on four trees. The symptom expression of the virus on these different varieties was then observed over a period of three years, with the results shown in Table III.

TABLE III.

TOLERANCE OF 42 VARIETIES OF APPLE TO THE VEIN-BANDING STRAIN OF APPLE MOSAIC VIRUS.

Susceptible		Partially tolerant	Tolerant
Very severe symptoms	Moderately severe symptoms	Very slight symptoms, usually showing on a few leaves only	No visible symptoms
Lord Lambourne	Miller's Seedling	Fortune	Ellison's Orange
Taunton Cross	Cox's O.P.	Lord Derby	Rival
Plymouth Cross	Melba	Rev. Wilks	Tydeman's Late Cox
Sweet Alford	Blenheim Orange	Gravenstein	Grenadier
	Newton Wonder	Early Victoria	St. Cecilia
	Bramley Seedling	Crimson King	Ashton Brown Jersey
	Sunset	Newport Cross	Sweet Coppin
	Epicure	Gascoyne's Scarlet	
	Allington Pippin	Tremlett's Bitter	
	Hereford Cross	Backwell Red	
	Gloucester Cross	Kingston Black	
	James Grieve	Bulmer's Norman	
	Lady Sudley	Stoke Red	
	Winston		
	Tardive Forestier		
	Court Royal		
	Foxwhelp		
	Yarlington Mill		
4 varieties	18 varieties	13 varieties	7 varieties

Of the 42 varieties investigated only three others developed symptoms as severe as those shown by Lord Lambourne. 31 others showed definite, though less severe symptoms, whilst 7 proved tolerant. The latter were presumably acting as symptomless carriers, though it will be necessary to check this by working buds from these trees back to virus-free Lambourne in order to confirm that they are in fact carrying the mosaic virus.

The systemic nature of apple mosaic.

One of the characteristics of plant viruses is their systemic nature, i.e. once introduced they spread from the point of infection, usually rapidly, throughout all the tissues of the plant. However, it is not uncommon to find apple trees which, year after year, display symptoms of mosaic on one or two branches only. The symptoms appear regularly on the same part of the tree each year with little apparent spread to other branches, suggesting that the virus has not become fully systemic. In order to investigate this point further buds were taken from such trees and worked on to maiden, virus-free trees of Lord Lambourne in the summer of 1951. Eight buds were taken from each of the mosaic infected trees, four from a branch showing visible symptoms of mosaic and four from an apparently healthy branch on the other side of the tree. The symptoms induced by these buds on the Lambourne indicator trees were observed in 1952 and 1953.

TABLE IV.

EXPERIMENT ON THE TRANSMISSION OF APPLE MOSAIC FROM TREES SHOWING LOCALISED SYMPTOMS.

Variety	Age in years	Condition of branch from which infection buds were taken	Symptoms produced on indicator trees of Lord Lambourne
Edward VII	25	Showing mosaic	Very severe
		No mosaic	Almost absent. A few flecks on one or two leaves only
Crawley Beauty	25	Showing mosaic	Very severe
		No mosaic	No symptoms
Bramley Seedling	20	Showing mosaic	Very severe mosaic and necrosis
		No mosaic	Well marked mosaic but not severe
Newton Wonder	28	Showing mosaic	No symptoms
		No mosaic	No symptoms
Cap of Liberty	48	Showing mosaic	Severe
		No mosaic	No symptoms

The results of this experiment, presented in Table IV, show that buds from mosaiced branches, as would be expected, usually transmit severe infection to the indicator trees. An exception was Newton Wonder where no

apparent transmission of the virus was obtained. It is possible that the variegation on this tree was of genetic and not of virus origin, or that it was caused by an unrecorded strain of mosaic virus to which Lord Lambourne is not susceptible. Posnette and Cropley record a similar failure to transmit the " severe " strain of mosaic to Lord Lambourne (3). Buds from apparently healthy branches of mosaic infected trees of Crawley Beauty and Cap of Liberty also failed to produce symptoms on Lord Lambourne, showing that the virus was not fully systemic in these trees. In view of the fact that both these trees had been displaying mosaic symptoms for at least eight years, and probably much longer, this localisation of the virus is remarkable. With Edward VII and Bramley Seedling some transmission of virus was obtained from apparently mosaic-free branches, but the symptoms which developed were much less severe than those caused by buds from branches visibly affected by mosaic.

It is concluded that here the apparently healthy branches were in fact carrying a low concentration of virus, sufficient to produce symptoms on the very susceptible Lord Lambourne, but insufficient to produce symptoms on the more tolerant Bramley Seedling and Edward VII. These results are not in complete agreement with those recently reported by Chamberlain, Atkinson and Hunter (4) who investigated the distribution of mosaic virus in Jonathan apple trees showing moderate apple mosaic symptoms. These authors found that, when buds were selected from branches where no symptoms occurred, the percentage of indicator trees developing symptoms was almost as great as when buds were secured from the axils of leaves showing symptoms, thus indicating that, in spite of the variation in symptom expression, the virus was fully systemic.

Summary.

(1) The distribution of latent rubbery wood virus in samples of M.I and M.II rootstocks from stoolbeds in different parts of the country was investigated by working them with virus-free Lord Lambourne.

(2) No rubbery wood virus was found in any of the seven samples of M.II tested.

(3) Only two out of six samples of M.I proved to be virus-free. Both these came from old-established nursery firms who obtained their parent stocks prior to 1930.

(4) Samples of seven different Malling stocks from the Long Ashton stoolbed were indexed for latent chat-fruit virus using Lord Lambourne as an indicator. 22% infection was found in M.IV, 6% in M.XVI and 4% in M.XII. Stocks M.I, II, VII and IX appeared to be free of chat-fruit virus.

(5) The tolerance of 42 varieties of apple to the vein-banding strain of apple mosaic virus was investigated. Seven were found to be tolerant, 13 partially tolerant and 22 susceptible.

(6) Transmission tests with buds taken from large apple trees showing localised mosaic symptoms, showed that in some the virus was not fully systemic, even though they had been infected for at least eight years.

Acknowledgments.

My thanks are due to Miss A. Rake for assistance in recording some of the experiments described in this paper.

REFERENCES.

(1) Luckwill, L. C. and Crowdy, S. H. (1950). Virus diseases of fruit trees : II. Observations on rubbery wood, chat-fruit and mosaic in apples. Progress report. *Ann. Rep. Long Ashton Res. Sta.*, 1949, 68–79.

(2) Posnette, A. F. and Cropley, R. (1952). The rubbery wood virus and apple propagation. *Ann. Rep. East Malling Res. Sta.*, 1951, 131–32.

(3) Posnette, A. F. and Cropley, R. (1952). A preliminary report on the strains of the apple mosaic virus. *Ann. Rep. East Malling Res. Sta.*, 1951, 128–130.

(4) Chamberlain, E. E., Atkinson, J. D. and Hunter, J. A. (1953). Note on the systemic nature of apple mosaic virus in apple trees. *N.Z. J. Sci. Tech.*, Sec. A., **34,** 551–552.

THE USE OF APOMICTIC SEEDLING ROOTSTOCKS FOR APPLES. PROGRESS REPORT.

By L. C. LUCKWILL and A. I. CAMPBELL.

Introduction.

In this country dessert and culinary apples are now raised almost exclusively on clonal rootstocks. Such stocks have two big advantages over the seedling crab or "free" seedling stocks that were formerly used for this purpose: firstly, uniformity, both of the stocks themselves and of the trees raised on them; and secondly, the control over the vigour and precocity of the tree which becomes possible through the use of selected clonal stocks of known performance. Against these advantages must be set the fact that clonal stocks are relatively costly to raise, compared with seedlings, and that, in common with other clonally propagated material, they are liable over the course of time to accumulate latent viruses which may affect the vigour of the stocks themselves and produce disease symptoms in the trees worked on them. Recent work on fruit tree viruses has shown that this has, in fact, already occurred with certain of the clonal apple rootstocks in use in this country (4). This latter danger does not exist when seedling stocks are used, since plant viruses, with few exceptions, are not seed transmissible. It is clear that the ideal series of apple rootstocks would be one that combined the uniformity and vigour range of the present clonal stocks with the cheapness and freedom from virus infection of seedling stocks. In theory, the use of apomictic seedling stocks might provide the answer to this problem.

Apomictic seeds are produced without pollination or fertilization, and in consequence all are genetically identical with the mother plant. Seedlings raised from such seeds therefore show great uniformity and can virtually be regarded as a "seedling clone." The phenomenon of apomixis occurs most commonly in polyploid plants, particularly triploids, and has been recorded in several genera of the *Rosaceae*, including *Rubus*, *Sorbus* and *Malus*, as well as in other families.

Apomixis in Malus.

The following species of *Malus* are stated by Sax (5) to be apomictic. All are asiatic in distribution and are triploids with 51 chromosomes:— *M.hupehensis* (=*M.theifera*); *M.toringoides*; *M.sikkimensis*. Apomixis was also found by Sax in a hybrid of *M.astranica* × *M.Sargentii*.

In *M.hupehensis* Dermen (3) found that both the pollen mother cells and the embryo-sac mother cells degenerate at an early stage of development. In the ovule one or more somatic cells of the nucellus enlarge to form a substitute embryo-sac, complete with synergids, antipodals, central nucleus and egg-cell. The egg-cell then develops without fertilization to give an embryo which, apart from its slower rate of growth, appears identical with a normal embryo resulting from sexual fusion. Dermen reported that from a large number of seeds he obtained only 39 seedlings, from which Tukey and Brase (6) conclude that this species would be unsuitable for use as a rootstock.

Sax (5), working at the Arnold Arboretum, budded 5 to 10 seedlings of a number of *Malus* species, including *M.toringoides* and *M.sikkimensis*, with the apple variety McIntosh. *M.toringoides* induced vigorous growth, whereas *M.sikkimensis* produced a semi-dwarf tree with a spreading growth habit. Both species were reported to have good root systems and to be immune or resistant to Crown Gall.

In view of this promising report by Sax, work was started at Long Ashton to investigate the possibility of using certain apomictic species of *Malus* as rootstocks for English varieties of apple, and the present paper gives some preliminary observations on the nursery performance of seedlings of *M. hupehensis*, *M.toringoides* and *M.sikkimensis*, budded with the varieties Cox's Orange Pippin, Lord Lambourne and Worcester Pearmain.

Experimental.

Seed production and germination.

Ripe fruits of the three species to be investigated were collected from trees growing in the Royal Botanic Gardens, Kew, in October 1950. After the fruits had softened they were pulped, and the seeds separated by washing through sieves. The seed content of all three species was found to be very low, averaging between one and two fully developed seeds per fruit. The remaining seeds were small and shrivelled and non-viable. The low seed content per fruit in these species is amply compensated by the very large number of small fruits produced. Thus, the yield of " good " seeds from *M.toringoides* and *M.hupehensis* was estimated at about 5,000, and that from *M.sikkimensis* at about 3,000 per 10 lb. of fruit.

The " good " seeds were sown in late October 1950, immediately upon removal from the fruit, in boxes of sterilized seed compost, which were then placed in a cold store at 4°C. until early February 1951 to after-ripen the seeds. Rapid germination occurred when the boxes were brought into the greenhouse and, under these conditions, the germination of the seeds of all three species was practically 100 per cent. The seedlings were pricked off in the cotyledon stage into 3-inch pots. After " hardening off " in a cold frame they were transplanted into open ground in April 1951, by which time the seedlings were about 5 inches high. 3 to 5 per cent. of dwarf seedlings, which were possibly tetraploids, were observed in all three species, and these were rogued during the summer of 1951. With the exception of these obvious rogues the seedlings of each species showed exceptional uniformity of leaf shape, colour, habit and rate of growth during their first season. No scab or mildew was observed on the seedlings during their period in the nursery, though some infection was present on nearby clonal stocks ; neither was any damage to the seedlings observed following the routine lime-sulphur sprays.

Nursery performance.

During the winter of 1951–52, 60 seedlings of each of the three species were lined out in the nursery, together with 60 each of the clonal Malling stocks IX and II. All the stocks were planted in runs of 30, randomised over the plot. They were budded during the summer of 1952, 10 of each run of 30 being budded with Lord Lambourne, 10 with Worcester and 10 with Cox's Orange Pippin. Plate I shows the condition of unbudded stocks of the three

apomictics, grown on an adjacent plot, during the winter of 1952–53. All three species have fibrous root systems and were found to transplant well. They also have an adequate length of clean stem at the base in which to insert the buds, thus eliminating the necessity of "cleaning up" the base of the stock prior to budding. During the budding operation the bark was found to lift easily and from the nurseryman's point of view the behaviour of these stocks was satisfactory up to this stage.

Graft compatibility.

During the summer of 1953 all the buds on *M.toringoides* and *M.sikkimensis* made good growth and showed no signs of incompatibility. At the end of the season the graft union of all three varieties on these two stocks was found to be strong. On *M.hupehensis* there was a total failure of all the buds. Although the bud "take" at first appeared to be good and the buds were still plump and green by the spring, they remained dormant and, by June, most of them were dead. On May 1st, by which time it had become obvious that the buds on this stock were not going to grow, half the stocks were reworked with the same varieties by whip-and-tongue grafting. The grafts remained alive for some months but failed to make any appreciable growth and eventually died. In no instance did the scion variety bring about the death of the *M.hupehensis* stock.

Growth of maiden trees.

In December 1953 observations were made on the growth of the maiden trees and measurements were taken of the height of each tree and its diameter at a point 12 inches above the union. The results are presented in Table I.

TABLE I.

MEAN HEIGHT (CM.) AND DIAMETER (MM.) OF ONE YEAR OLD TREES OF COX'S ORANGE PIPPIN, LORD LAMBOURNE AND WORCESTER PEARMAIN, WORKED ON TWO CLONAL AND TWO APOMICTIC SEEDLING STOCKS.

Stock	Cox		Lambourne		Worcester		Mean	
	Height	Diam.	Height	Diam.	Height	Diam.	Height	Diam.
M.IX	82	7·1	82	7·1	86	8·8	83	7·7
M.II	113	9·1	84	9·0	106	9·6	101	9·2
M.sikkimensis ..	123	10·4	113	9·4	101	8·8	112	9·5
M.toringoides ..	137	11·3	117	8·6	127	10·6	127	10·2

For the varieties Cox and Worcester the most vigorous maiden trees were undoubtedly those on *M.toringoides*. On *M.sikkimensis* the growth of these two varieties was less than on *M.toringoides* (difference significant at 1% level),

and was approximately equal to that made on the M.II. For the variety Lord Lambourne the order of vigour of the stocks was the same, but the difference in height between the trees on the two apomictic stocks was not significant. As would be expected the smallest trees of all three varieties were those on M.IX. Many of the Lord Lambourne trees on this stock were found to be slightly rubbery, but no signs of rubbery wood were found in trees of this variety worked on either *M.toringoides* or *M.sikkimensis.*

Root structure.

The work of Beakbane and Thompson (1, 2) has shown that the vigour and precocity of apple rootstocks is correlated with their root structure, particularly with the thickness of the root bark and the proportion of living tissue in the wood, and that these features can be used as a guide for predicting the probable performance of new stocks.

The percentage area of bark in cross sections of roots of *M.toringoides* and *M.sikkimensis,* in relation to root diameter, is shown in Fig. 1. In the same diagram are shown corresponding data for typical dwarfing (M.IX), semi-dwarfing (M.VII) and vigorous (M.XII) stocks, taken from Beakbane and Thompson's paper (2). It is clear that both the apomictic stocks should, on this feature, be classed as vigorous. There are, however, well marked differences between them, the bark of *M.sikkimensis* being significantly thicker

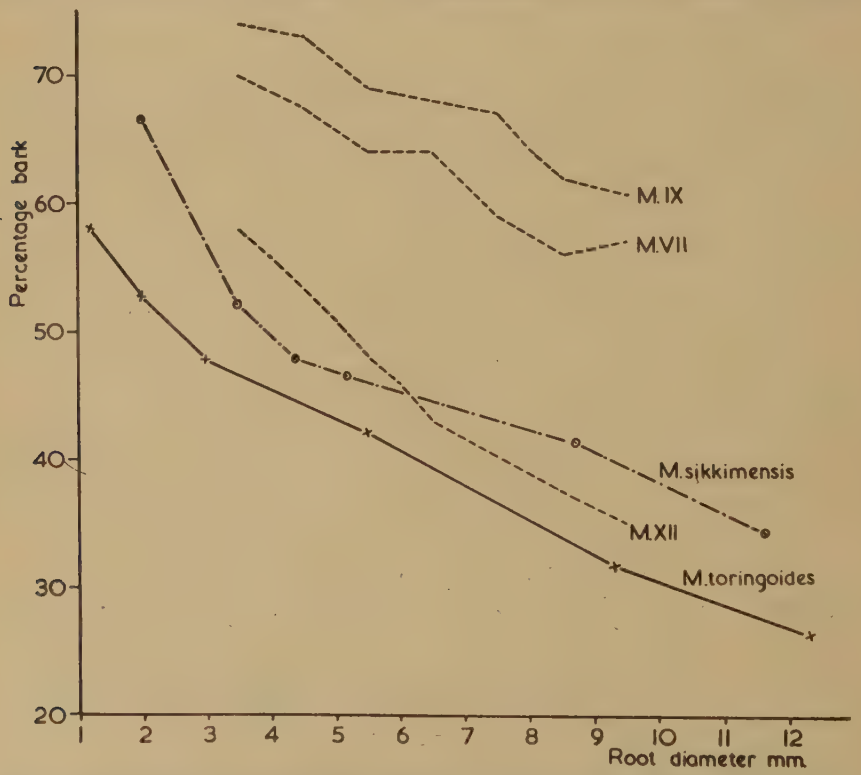


Fig. 1. Graphs showing percentage bark in cross-sections of roots of *Malus toringoides* and *M.sikkimensis* in relation to root diameter. Corresponding data for three Malling rootstocks, taken from the work of Beakbane and Thompson (2) are shown for comparison.

than that of *M.toringoides*. The results of the bark measurements are supported by a detailed examination of the wood structure of the roots of these two stocks. The wood of *M.toringoides* possesses all the features characteristic of very vigorous stocks. The vessels are large (40–70 μ diam.), the medullary rays narrow and composed of cells much elongated radially, and the wood contains a high proportion of fibres with relatively few parenchyma cells. The wood anatomy of *M.sikkimensis*, on the other hand, has features which suggest that it will prove a less vigorous stock than *M.toringoides* for, although the fibre/parenchyma ratio is high, the vessels are much smaller (25–50 μ. diam.) and the medullary rays wider and composed of less elongated cells.

Discussion.

These trials have shown that of the three apomictic species tested, seedlings of *M.toringoides* and *M.sikkimensis* show promise, at least to the nursery stage, as rootstocks for apples. The indication from the present work is that the former may prove to be a very vigorous stock and the latter somewhat less vigorous, which is in agreement with Sax's observations on the growth of McIntosh on these two species. Although these stocks may prove too vigorous for the production of bush trees of dessert varieties, they might well be of value for the raising of standard cider trees with a greater degree of uniformity than those at present grown on "free" seedling stocks. They might also prove useful in the propagation of mother trees of promising new varieties of apple where it is essential to use stocks that can be guaranteed free of virus infection.

It is possible that further investigation of the triploid species and hybrids within the genus *Malus* will reveal other apomictic species suitable for use as rootstocks, and that some of these may possess semi-dwarfing characters.

Summary.

(1) Seedlings of three apomictic species of *Malus* were raised and budded with the varieties Cox's Orange Pippin, Lord Lambourne and Worcester Pearmain.

(2) All three varieties proved incompatible with *M.hupehensis* but made good maiden growth when worked on *M.sikkimensis* and *M.toringoides* seedlings.

(3) Apart from 3 to 5 per cent. of dwarfs, which were rogued at an early stage, the growth of these apomictic seedlings and of the maiden trees worked on them was exceptionally uniform.

(4) A study of root structure suggests that *M.toringoides* will prove a vigorous stock and *M.sikkimensis* somewhat less vigorous. Similar indications were obtained from the amount of growth made by the trees in their first year. Both of these species had fibrous root systems and showed a satisfactory nursery performance.

Acknowledgment.

We wish to express our thanks to Mr. W. M. Campbell, N. D. H., Curator of the Royal Botanic Gardens, for permission to collect fruits of the *Malus* species used in this work.

REFERENCES.

(1) Beakbane, A. B. and Thompson, E. C. (1939). Anatomical studies of stems and roots of hardy fruit trees : II. The internal structure of the roots of some vigorous and some dwarfing apple rootstocks and the correlation of structure with vigour. *J. Pomol.*, **17,** 141–149.

(2) —— and —— (1947). Anatomical studies of stems and roots of hardy fruit trees : IV. The root structure of some new clonal apple rootstocks budded with " Cox's Orange Pippin." *J. Pomol.*, **23,** 206–211.

(3) Dermen, H. (1936). Aposporic parthenogenesis in a triploid apple, *Malus hupehensis*. *Journ. Arnold Arboretum*, **17,** 90–105.

(4) Luckwill, L. C. and Crowdy, S. H. (1950). Virus diseases of fruit trees : II. Observations on rubbery wood, chat fruit and mosaic in apples. *Ann. Rep. Long Ashton Res Sta.*, 1949, 68–79.

(5) Sax, K. (1949). The use of *Malus* species for apple rootstocks. *Proc. Amer. Soc. hort. Sci.*, **53,** 219–220.

(6) Tukey, H. B. and Brase, K. D. (1938). Random notes on fruit tree rootstocks and plant propagation III. *New York State agric. exp. Sta., Geneva,* Bul. No. 682.

(a) (b) (c)

Two-year old seedlings of (*a*) *Malus toringoides*, (*b*) *M.sikkimensis* and (*c*) *M.hupehensis*.
Scale 0·6″ = 1ft.

2 : 4 : 5-TP AS A FRUIT-RIPENING AGENT : I. APPLE var. WORCESTER PEARMAIN.

By D. L. ABBOTT.

Introduction.

It has been reported that 2:4:5-trichlorophenoxy acetic acid (2:4:5 T), applied as an aqueous spray, is active in advancing the maturity of figs (1), apples and peaches (8), apricots (3) and plums (9). In this country such a fruit-ripening spray might be of particular value in hastening the maturity of Worcester Pearmain and thus meeting the demand for an early dessert apple. The grower of other varieties might also extend his picking period by spraying parts of his orchard.

Luckwill (7), comparing several growth substances as fruit-thinning agents for apples, found that while 2:4:5 T had no noticeable effect on the ripening of Laxton's Superb, the related compound α (2:4:5-trichlorophenoxy)-propionic acid (2:4:5 TP) advanced fruit maturity very considerably. 2:4:5 TP also seems to have been more effective than 2:4:5 T in ripening the fruit of the McIntosh apple when these compounds were used as pre-harvest drop sprays (4). 2:4:5 TP was, therefore, selected for trial as a fruit-ripening agent for apples and a pilot experiment was carried out in 1952, in which branches of Worcester Pearmain were sprayed with this compound over a wide range of concentrations and at different times. Though damage to both foliage and shoots resulted from sprays of concentrations above 50 p.p.m., it was apparent that treatment with 2:4:5 TP at concentrations of 20–50 p.p.m. applied 6 weeks before the normal picking date resulted in the production of ripe fruit 1–2 weeks in advance of controls.

A further trial was carried out in 1953 and the results of this experiment are given below.

Experimental.

2:4:5 TP was applied to whole trees of Worcester Pearmain as an aqueous spray, without the addition of wetting agents, at concentrations of 30 and 50 p.p.m. The applications were made with a power sprayer on the 15th July and the 4th August. Control trees were not sprayed. 4 replicates of the 5 treatments were randomised amongst 20 mature bush trees, and buffer rows afforded protection against spray drift.

Subsequently random samples of 10 fruits were taken at intervals from each of the four trees of a treatment and roughly graded by eye for colour, the 10 fruits at each extreme being discarded and the remaining 20 fruits being used for the following tests :—

(1) *Fruit colour.* 80 discs of skin, cut with a 1·25 cm. diam. cork borer, one from each quarter of the 20 fruits, were macerated in acetone in a blender. The pulp was filtered, washed with ether, and the filtrate extracted successively by water and a saturated solution of KOH in methyl alcohol to obtain the three fractions : (1) anthocyanins ; (2) saponified chlorophylls ; (3) carotenes and xanthophyll. The concentration of the pigments in these extracts was then measured in a Spekker absorptiometer. Since comparisons of colour only were required in this experiment, absolute quantities of the pigments were not

determined and the results for pigment content are expressed in arbitrary units.

(2) *Hardness* was determined by measuring the pressure required to force a $\frac{1}{2}''$ diam. plunger into the flesh to a depth of $\frac{3}{16}''$, using a modified form of the apparatus described by Hinton (6).

(3) *Titratable acidity* of the expressed juice was determined by titration against N/6·7 NaOH (2). Results are expressed as percentage malic acid.

(4) *Seed colour* was estimated by eye as a percentage of the full brown colour of ripe seed.

(5) *Starch content.* The apples were cut transversely and treated with iodine solution. The percentage area of the cut surface showing the starch reaction was estimated and taken as a measure of the starch content of the fruit (5).

An attempt to determine the sugar content of the fruit was invalidated by a faulty extraction technique.

When judged ready for harvest, the fruit from the 4 trees of each treatment was picked, and a random sample of 200 fruits was retained in the fruit store for observation of storage quality. One branch on each of 2 trees of a treatment, however, was left unpicked for final tests to be made on the fruit at the time when the controls were harvested.

Results.

Since good colour is a very desirable quality in the variety Worcester Pearmain, the effect of 2:4:5 TP on the anthocyanin content of the fruit is of particular importance.

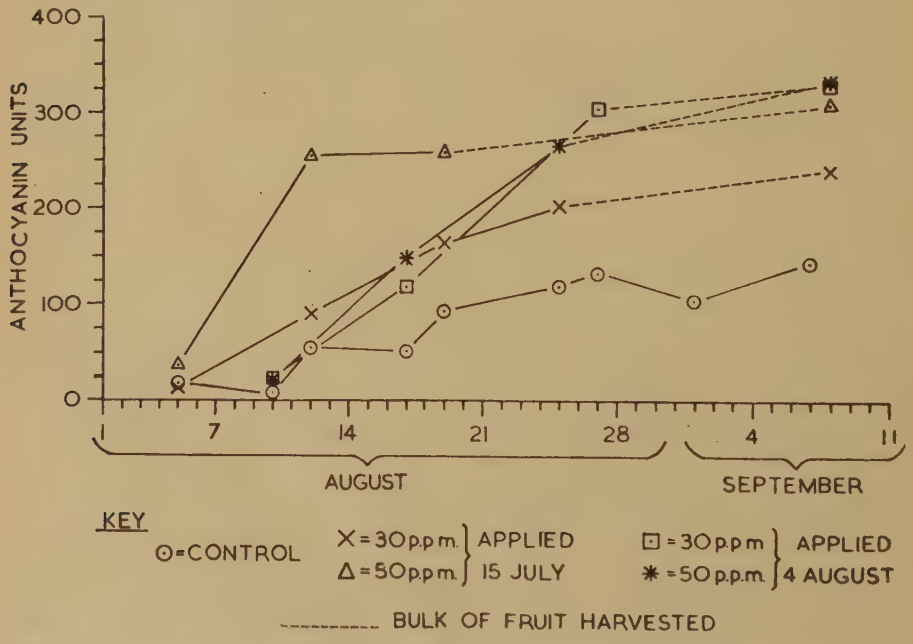


Fig. 1. The effect of 2:4:5 TP on the anthocyanin content of Worcester Pearmain apples.

All treatments produced fruit of higher anthocyanin content, and consequently more brilliantly coloured, than the controls. While applications of

2:4:5 TP at both 30 and 50 p.p.m. on 4th August gave similar anthocyanin contents, the application of 30 p.p.m. on 15th July gave an anthocyanin content only intermediate between that given by the 50 p.p.m. treatment and the control. Moreover this intermediate anthocyanin content given by the early application of 30 p.p.m. was due, not to partial ripening of individual apples, but to uneven ripening of the fruit of a tree. Thus it seems that a critical concentration of 2:4:5 TP is required in each fruit to initiate the ripening mechanism and that the critical concentration needed is lower as the season advances.

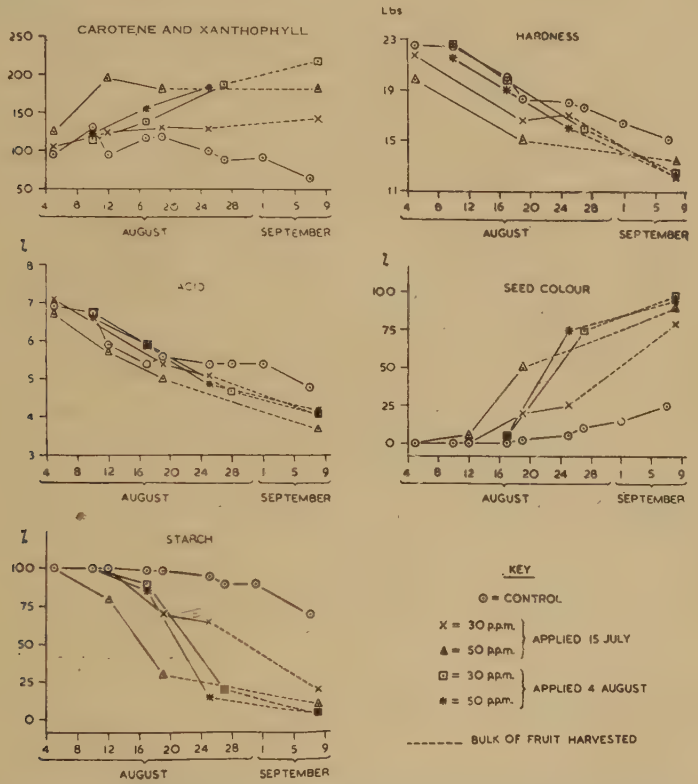


Fig. 2. The effect of 2:4:5 TP on the carotene and xanthophyll content, hardness, acid and starch content, and seed colour of Worcester Pearmain apples.

A similar response to treatment is seen in Fig. 2 which shows the effect of 2:4:5 TP on carotene and xanthophyll content, hardness of flesh, acid and starch content and seed colour. Chlorophyll content is not shown, as it was found that these pigments, after saponification, yielded an extract of approximately the same colour and density as that of the decomposition products of the chlorophylls present in the ripe fruit, and did not therefore provide a reliable measure of the green colour of the fruit.

Since hardness of flesh, acid and starch content and seed colour are all influenced by treatment, it is apparent that 2:4:5 TP hastens not only the development of colour, but that it also influences the general metabolism of the fruit and advances the whole process of maturation.

TABLE I.

HARVEST DATES, FRUIT SIZE AND QUALITY FOLLOWING TREATMENTS WITH 2:4:5 TP.

Concentration of 2:4:5 TP (p.p.m.)	Date of spraying	Date of harvest	Days in advance of control	Mean fruit weight (g.)	Remarks
0	—	8th Sept.	0	103	Control-harvested at middle of Worcester picking period
30	15th July	24th Aug.	15	84	Uneven ripening
50	„	19th Aug.	20	70	Inferior flavour
30	4th Aug.	27th Aug.	12	81	Very good appearance and normal flavour
50	„	„	12	83	

Table I shows that marketable fruit was obtained as early as 3 weeks before the normal picking date, but size was small and flavour poor. Fruit harvested 12 days in advance of the control was of excellent quality. It seems likely that treatment with 2:4:5 TP at 40 p.p.m. applied 6 weeks before the normal picking date will prove to give the earliest ripening without lowering the quality, but further trials must be carried out before recommendations can be made. Furthermore, though no damage has yet been observed, the growth and cropping of the trees next season must be examined to determine whether the trees have suffered any delayed injury as a result of treatment.

As might be expected, fruit maturation was advanced not only on the tree, but also during storage. Tests on fruit which had been retained in a cool fruit store showed that whereas the control fruit was still sound in mid-October, fruit sprayed on the 4th August was nearing the end of its storage life, while fruit sprayed on the 15th July was shrivelled and no longer saleable.

Summary.

(1) α-(2:4:5 trichlorophenoxy) propionic acid was applied at 30 and 50 p.p.m. to trees of Worcester Pearmain on the 15th July and the 4th August as a ripening spray.

(2) Ripe fruit of very good quality was harvested 12 days before the normal picking date. Marketable fruit was obtained as early as 20 days before the normal picking date, though the size and flavour were not fully developed.

(3) Storage quality of fruit was impaired following treatment with 2:4:5 TP, but not sufficiently to interfere with normal marketing.

Acknowledgments.

Thanks are due to Universal Crop Protection Ltd. for the generous gift of the 2:4:5 TP, and to Mr. C. W. Harper for applying the sprays. Thanks are also due to Mr. L. F. Burroughs, who carried out the determinations of titratable acidity.

REFERENCES.

(1) Blondeau, Rene and Crane, Julian, C. (1948). Early maturation of Calimyrna fig fruits by means of synthetic hormone application. *Science*, **108,** 719-720.

(2) Burroughs, L. F. (1947). The determination of the titratable acidity of apple juice and cider. *Ann. Rep. Long Ashton Res. Sta.*, 1946, 127-132.

(3) Crane, Julian C. and Brooks, Reid M. (1952). Growth of apricot fruits as influenced by 2:4:5-trichlorophenoxyacetic acid application. *Proc. Amer. Soc. hort. Sci.*, **59,** 218-224.

(4) Hoffman, M. B. and Edgerton, L. J. (1952). Comparisons of naphthaleneacetic acid, 2:4:5-trichlorophenoxypropionic acid and 2:4:5-trichlorophenoxyacetic acid for controlling the harvest drop of McIntosh apples. *Proc. Amer. Soc. hort. Sci.*, **59,** 225-230.

(5) Hinton, J. C. (1932). Studies on maturity of fruit : III. Starch content in relation to maturity of apples grown under various orchard conditions. *Ann. Rep. Long Ashton Res. Sta.*, 1931, 54-67.

(6) Hinton, J. C. (1935). Studies on maturity of fruit : V. The effect of conditions during growth on the progress of softening and on the loss of total weight in apples during storage. *Ann. Rep. Long Ashton Res. Sta.*, 1934, 53-83.

(7) Luckwill, L. C. (1952). Trials with growth substances as fruit-thinning agents. *Ann. Rep. Long Ashton Res. Sta.*, 1951, 33-40.

(8) Marth, P. C., Harley, C. P. and Havis, A. L. (1950). Effect of 2:4:5-trichlorophenoxyacetic acid on ripening of apples and peaches. *Science*, III, 331-2.

(9) Zielinski, Quentin B. (1951). Effects of 2:4:5-trichlorophenoxyacetic acid on the maturation of prunes. *Proc. Amer. Soc. hort. Sci.*, **58,** 65-68.

GROWTH SUBSTANCES AS FRUIT-THINNING AGENTS FOR APPLES: PROGRESS REPORT.

By D. L. ABBOTT.

Introduction.

Experiments on the use of 1-naphthalene acetic acid (NAA) as a post blossom thinning agent for apples, carried out at Long Ashton in 1950, 1951 and 1952, have been reported in previous publications (1, 4). The present paper describes further trials with this substance on the varieties Emneth Early (Early Victoria), Lane's Prince Albert and Laxton's Superb, carried out in 1953. The trials were designed to investigate the relation between the concentration of the spray and the amount of thinning, and the effect of different degrees of thinning on the size and quality of the crop.

In order to obtain further information on the mechanism of the thinning action, a small experiment was also carried out to determine the effect of NAA applied to branches that had been previously thinned by hand.

Effect of different concentrations of NAA.

Method.

As in previous trials the treatments were again applied to individual limbs of mature bush trees, adjacent limbs being protected from spray drift where necessary with waterproof screens. No evidence has been obtained of translocation of the growth substance from sprayed to unsprayed limbs of such trees, and it seems justifiable to assume that the limbs behave as independent units in their response to thinning sprays.

Previous experiments have shown that, in order to bring about an increase in mean fruit weight, the thinning spray should be applied not later than 10 days after petal-fall. In 1953, therefore, the sprays were applied on the 8th day after petal-fall to Early Victoria, and on the 9th day to Lane's Prince Albert and Laxton's Superb.

NAA was used as an aqueous spray, without wetters, at concentrations of 2, 5, 10, 25, 50 and 100 p.p.m. Control branches were not sprayed. There were 8 replicates of the 7 treatments, randomised amongst 56 branches of each of the three varieties.

Results.

Table I shows that NAA was effective in thinning all three varieties, but varietal differences in response again occurred. Lane's Prince Albert was the most, and Early Victoria the least readily thinned. It is not known whether this was due to differences in varietal susceptibility or to differences in the physiological states of the trees. There occurred, for example, a very severe shedding of fruitlets even from the control branches of Lane's Prince Albert following a profusion of blossom and high initial set. In consequence only 10 fruits matured per 100 blossom clusters. By contrast Early Victoria carried only a moderate amount of blossom, but the drop of young fruitlets from the control branches was light and 62 fruits matured per 100 blossom clusters.

Application of treatments to Laxton's Superb was commenced 8 days after petal-fall, but during spraying operations it started to drizzle and, on completion of treatments at 2 and 100 p.p.m., further spraying was postponed until the following day. The drizzle continued for approximately 1 hour and was followed by heavy rain which lasted for a further 5 hours. However, treatment at 100 p.p.m. under these conditions resulted in thinning equivalent to that which would have been obtained by treatment at approximately 20 p.p.m. applied in dry weather.

TABLE I.

FRUITS (LESS CHATS) MATURED PER 100 BLOSSOM CLUSTERS AFTER TREATMENT WITH NAA.

Conc. NAA (p.p.m.)	Variety and time of application (days after petal-fall)		
	Early Victoria	Lane's Prince Albert	Laxton's Superb
	8 days	9 days	9 days
Control ..	62	10	41
2	61	7	44*
5	54	**4**	35
10	46	**3**	**22**
25	**31**	**1**	**19**
50	**22**	**1**	**12**
100	**3**	**1**	**22***

Figures in bold type differ significantly from the control (P=0.05).
*Applied during rain.

It is apparent from Fig. 1 that the relationship between concentration of NAA and its thinning effect is approximately logarithmic over the range of concentrations tested.

An analysis of fruit into size groups (Table II) shows that in no treatment where thinning was significant was there any increase over the controls in the number of marketable fruits produced per 100 blossom clusters. The results of this experiment confirm previous experience that, although NAA is an effective post-blossom thinning agent, no increase in size of marketable crop can ordinarily be expected to result from the use of this substance under conditions obtaining at Long Ashton. No recommendations for general use can therefore be made at present.

Effect of hand thinning on subsequent treatment with NAA.

Method.

18 branches, each carrying 100–150 blossom clusters, were selected from 4 mature bush trees of Laxton's Superb. 12 of these branches were hand thinned at full-bloom. Two methods were employed : (a) removal of all the flowers from 4 of every 5 blossom clusters, but avoiding damage to the spur

leaves (clusters thinned); and (b) thinning to 1 flower per cluster (flowers thinned). Since each cluster contained on average 5 flowers, both treatments resulted in a reduction to one-fifth of the original number of flowers. The remaining 6 branches were left unthinned as controls.

TABLE II.

DISTRIBUTION OF FRUIT INTO SIZE GROUPS.
(FRUITS MATURED PER 100 BLOSSOM CLUSTERS).

	Conc. NAA (p.p.m.)	Chats $<1\frac{3}{4}''$	Unmarketable $1\frac{3}{4}$—$2\frac{1}{4}''$	Marketable $>2\frac{1}{4}''$
Early Victoria	Control	7·2	58·8	3·0
	2	4·1	53·6	7·7
	5	4·2	49·3	4·3
	10	2·3	41·7	4·4
	25	4·4	28·8	2·6
	50	15·0	18·9	2·6
	100	58·6	2·9	0·3
Lane's Prince Albert	Control	0·1	0·3	9·5
	2	0	0·7	6·2
	5	0	0·3	3·3
	10	0	0·1	2·4
	25	0	0·1	0·9
	50	0·3	0·8	0·4
	100	0·6	0·9	0·1
Laxton's Superb	Control	1·1	20·1	20·8
	2*	2·4	15·4	28·2
	5	9·5	18·5	16·1
	10	8·9	9·7	12·5
	25	20·4	11·1	8·2
	50	39·2	8·8	3·5
	100*	16·0	12·9	9·1

Concentrations in bold type are those effecting significant thinning.
*Applied during rain.

3 branches of each hand-thinning treatment and 3 unthinned branches were then sprayed with NAA at 25 p.p.m. 9 days after petal-fall. The fruits were counted, and their size was measured on the tree with callipers at intervals throughout the growing season.

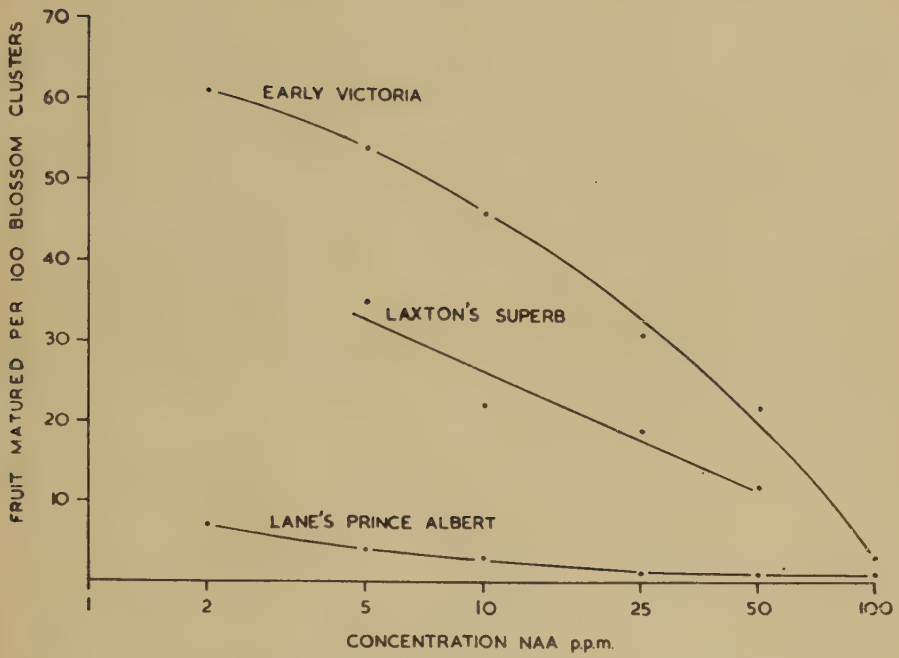


Fig. 1. Degree of thinning plotted against log. concentration.

Results.

Fig. 2 shows the distribution of fruitlets into size groups on 10th July, after completion of the June drop.

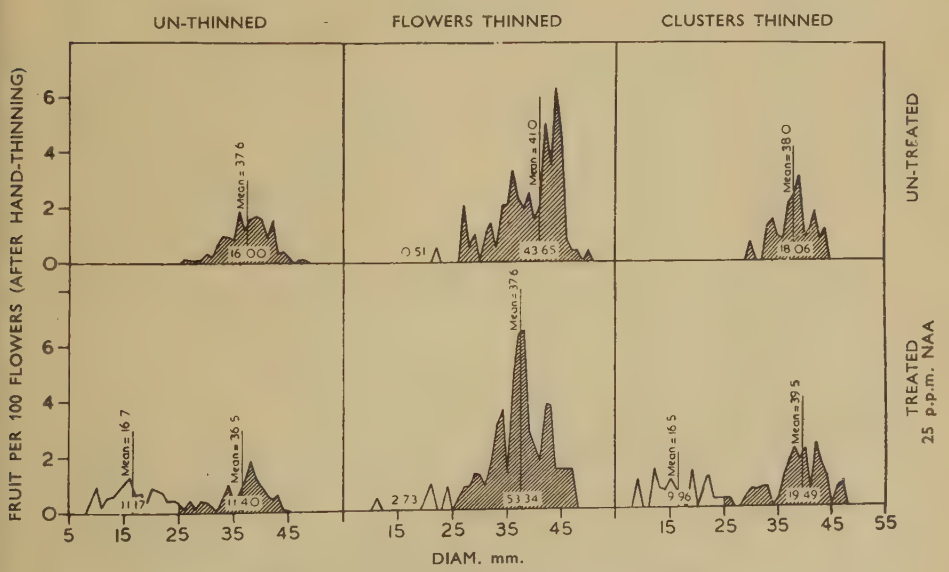


Fig. 2. Distribution of fruit in sizes on 10th July.

NAA has the effect of holding on the tree many fruitlets that would otherwise have abscissed. The fruitlets on sprayed branches were found to fall into 2 groups. Those fruitlets below approximately 25 mm. diam. had ceased growth and were destined eventually to fall or remain on the tree as "chats," while those above approximately 25 mm. diam. were found to continue growth to maturity. The number and distribution of fruitlets was similar on both the unthinned branches and those branches on which clusters had been thinned, although treatment of the latter branches with NAA did not reduce the number of fruitlets over 25 mm. diam. as it did on the unthinned branches. Those branches on which flowers had been thinned, however, carried $2\frac{1}{2}$ times as many fruitlets per 100 flowers as did the unthinned branches or those on which clusters had been thinned, and treatment with NAA resulted in only a very small group of fruitlets below 25 mm. diam. Rather did those fruitlets whose abscission had been delayed by NAA continue to grow and add to the group above 25 mm. diam.

These results suggest that in the early stages of fruit development the spur behaves as an independent unit and the fruitlets compete for foodstuffs supplied chiefly by the leaves of their own spur, receiving little or no maintenance from adjacent parts of the branch. The difference, then, in the effect of NAA on the branches hand-thinned by the two different methods can be accounted for in terms of competition. It would seem that when several fruitlets develop on a spur and competition is already severe, the application of NAA in some way still further limits the availability of foodstuffs to an extent sufficient to lead to the seed abortion observed by Luckwill (3) to cause fruit drop. When, however, there is only one fruitlet on the spur, foodstuffs are available in excess and any reduction resulting from the application of NAA is insufficient to bring about seed abortion. Furthermore any fruitlets that would otherwise have dropped, but whose abscission has been delayed by NAA, have an abundant supply of foodstuffs with which to make further growth.

The results suggest that conditions favouring the availability of foodstuffs to the developing fruitlets will minimise the thinning effect of NAA. They provide experimental evidence to support the suggestion made in 1952 (1) to account for the difference in the thinning effect of NAA on Miller's Seedling in 1950 and 1952. They also confirm the experimental results of Struckmeyer and Roberts (5) and are in accordance with the findings of Langer (2) that fruit from vigorous buds is less easily thinned than that from weak buds.

Summary.

(1) Branches of Early Victoria, Lane's Prince Albert and Laxton's Superb were sprayed with NAA at 2, 5, 10, 25, 50 and 100 p.p.m. 8 or 9 days after petal-fall.

(2) The relationship between spray concentration and thinning effect is shown to be approximately logarithmic.

(3) Although all three varieties were thinned by treatment, the size of the marketable crop was reduced and no recommendations for the general use of NAA as a post-blossom thinning agent can be made.

(4) An experiment in which branches of Laxton's Superb were hand-thinned prior to treatment with NAA suggests that an abundant supply of foodstuffs to the developing fruitlets minimises the thinning effect of NAA.

Acknowledgment.

Thanks are due to Miss A. J. Beagles for assistance in spraying and recording.

REFERENCES.

(1) Abbott, D. L. (1953). Growth substances as fruit-thinning agents for apples and pears : progress report. *Ann. Rep. Long Ashton Res. Sta.*, 1952, 40-44.

(2) Langer, C. A. (1953). The relationship between apple tree vigour and naphthalene acetic acid thinning sprays. *Mich. Agr. Exp. Sta. Quart. Bul.*, **35,** 467-73.

(3) Luckwill, L. C. (1953). Studies of fruit development in relation to plant hormones : II. The effect of naphthalene acetic acid on fruit set and fruit development in apples. *J. hort. Sci.*, **28,** 25-40.

(4) —— (1952). Trials with growth substances as fruit-thinning agents. *Ann. Rep. Long Ashton Res. Sta.*, 1951, 33-40.

(5) Struckmeyer, B. E. and Roberts, R. H. (1950). A possible explanation of how naphthalene acetic acid thins apples. *Proc. Amer. Soc. hort. Sci.*, **56,** 76-78.

A SURVEY OF PERRY PEARS IN THE WEST MIDLANDS: I. NORTH-WEST GLOUCESTERSHIRE.

By R. R. WILLIAMS.

Introduction.

Increasing interest during recent years in the commercial production of perry has led to a demand for more knowledge concerning the distribution, identification, cultivation and vintage quality of the numerous varieties of perry pears to be found growing in the West Midlands. A detailed survey of the chief perry growing areas in Gloucestershire, Herefordshire and Worcestershire has therefore been undertaken, and the present paper deals with the varieties found in one of these areas, north-west Gloucestershire. The parishes covered in this part of the survey are shown in Fig. 1. In subsequent papers it is hoped to extend the survey to other areas and to give detailed pomological descriptions of the most important varieties.

The nomenclature of the perry pears is at present in a very confused state. The same variety may be known in different parishes under a number of different names; and not infrequently a single name may refer to several different varieties, according to locality. In the following list an attempt has been made to resolve some of this confusion by following the preferred name of each variety with a list of synonyms. Synonyms whose rejection is advised are listed with a cross reference to the preferred name. It should be noted that the distribution shown in the list is that of the name, not of the variety. The variety Rock, for example, is widely distributed throughout the area under the name of Brown Huffcap. The name Rock, on the other hand, whilst common in other parts of the West Midlands, is rare in this part of Gloucestershire.

Many perry pears are extremely local in distribution, being confined to one or a few parishes. A few, however, are more widely distributed, being found throughout the area and often in the adjacent perry growing areas of Herefordshire and Worcestershire. The cultivation of some of these widely distributed varieties has now declined to such an extent that they may be classed as rare, whilst others are still relatively common.

Although numerous references to perry pears occur in the literature of the 17th and 18th century, the earliest pomological work that is useful in the identification of varieties in that of T. A. Knight (1) published in 1811. Further descriptions and illustrations of perry pears are to be found in the publications of the Woolhope Naturalist Club between 1876 and 1886, edited by Hogg and Bull (2, 3). Since that date the only publication of note is a paper read in 1923 to the Royal Horticultural Society by the late Dr. H. E. Durham (4). This paper, together with an unpublished album of photographs presented to the Society, contains information concerning over 100 varieties. It has proved possible to trace a large proportion of the specimen trees photographed by Durham and a careful examination has been made of these.

A further valuable aid in the identification of perry pears is the museum orchard at Broxwood, Herefordshire, established in 1925 by Messrs. H. P.

Bulmer as a result of Durham's work, and frequent reference has been made to this type collection of 36 varieties during the course of the present survey. Between 1909 and 1920 Long Ashton distributed trees of 15 selected perry

Fig. 1. A Parish Map of North-west Gloucestershire.

varieties for the establishment of trial orchards in various localities in the West Midlands. Many of these orchards have been visited and the varieties which they contain, many of them not indigenous to the locality, are shown in the list.

Names, Synonyms and Distribution.

Varieties which are illustrated in the works of Knight, Hogg and Bull, or Durham are indicated by the letters K, H & B, or D respectively, placed after

the varietal name. An asterisk preceding the varietal name indicates the varieties most commonly found in cultivation at the present time.

Arlingham Squash .. H & B, D. *Syn.:* Squash Pear, Old Squash, Old Taynton Squash. *Distr.:* Taynton, uncommon; frequently confused with Taynton Squash; once widely grown.

Awrel .. .. .. see Oldfield. *Distr.:* Dymock, uncommon.

*Aylton Red .. .. H & B, D. *Distr.:* Newent, Dymock, Oxenhall, common; it has not been possible to distinguish this variety from the Red Pear.

Bache's White.. .. see White Bache.

*Barland.. .. .. K, H & B, D. *Distr.:* all parishes, common.

Barn .. .. .. see Barnet. *Distr.:* Newent, Dymock, uncommon.
and see Turners Barn. *Distr.:* Newent, common.

Barnet .. .. .. *Syn.:* Barn. *Distr.:* Dymock, uncommon; distributed by Long Ashton.

Bastard .. .. *Distr.:* all parishes, common; used to denote a seedling.

Bastard Barland .. see White Longdon. *Distr.:* Westbury, Blaisdon, uncommon.

Bastard Longdon .. *Distr.:* Blaisdon, Longhope, Huntley, uncommon; original tree still growing in Longhope.

Bastard Sack .. .. *Distr.:* Taynton, uncommon; seedling of considerable promise.

Beech White .. .. see White Bache.

Billy Thurston .. see Thurston Red. *Distr.:* Newent, Upleadon, frequent.

Billy Williams .. *Distr.:* Longhope, Blaisdon, uncommon; once more widely grown.
and see Nailer. *Distr.:* Longhope, Westbury, Newnham, Taynton, common.

*Black Huffcap.. .. H & B? *Syn.:* Black Pear, Huffcap, Uffcap (Uffcup); there are numerous Black Huffcaps, any of these listed below could be type illustrated by Hogg and Bull. *Distr.:* Westbury, uncommon; variety once grown on a considerable scale in this parish.
and *Distr.:* Blaisdon, uncommon; closely resembles that illustrated by T. A. Knight, including leaves.
and see Rock. *Distr.:* Newent, Highnam.
and see Yellow Huffcap. *Distr.:* Littledean, East Dean.

Black Pear .. .. see Black Huffcap.

Bloody Bastard .. *Distr.:* Staunton, uncommon; very similar to the dessert pear Sanquinole.

*Blakeney Red .. H & B, D. *Syn.:* Circus Pear, Painted Lady (Painted Pear)? *Distr.:* all parishes, common.

Boy .. .. .. *Distr.:* Churcham, Longhope, uncommon; a very early variety.

Brandy .. .. .. *Distr.:* Tibberton, Taynton, Longhope, uncommon.

Brockhill .. .. D. *Distr.:* Dymock, uncommon.

Brockle (Brockull) .. see Red Longdon. *Distr.:* Dymock.

*Brown Bess .. .. *Distr.:* Newent, uncommon; culinary pear frequently seen in other parts of Gloucestershire.

*Brown Huffcap .. see Rock. *Distr.:* Newent, Taynton, Tibberton, Rudford, Hartbury, common.

Brown Longdon .. see Green Longdon.

*Brown Russet .. D. *Distr.:* Bromsberrow; more common in South Worcestershire.

Butt .. .. .. H & B, D. *Distr.:* most parishes, common.

Cannock .. .. *Distr.:* East Dean, general purpose pear.

Chaceley (Chaseley) Green .. H & B? D. *Distr.:* Newent.
and H & B? *Distr.:* Chaceley; differs from Newent Chaceley Green and from Durham's photograph.

Chandos Huffcap .. see Yellow Huffcap; Durham's name for this variety.

Chaxhill Rough .. *Syn.:* Rough. *Distr.:* Westbury, uncommon; reported but not yet examined.

Choke Pear (Chokers) .. .. see Moorcroft; an old term for perry pears now usually restricted to this variety.

Cider Pear .. .. see Red Longdon.

Circus Pear .. .. see Blakeney Red. *Distr.:* Westbury, frequent.

Claret .. .. .. *Distr.:* Dymock, uncommon; trees from Long Ashton.

Clipper Dick .. .. *Distr.:* Westbury, uncommon; a very early general purpose pear.

Cluster Top .. .. see Holmer.

Coppy .. .. .. H & B, D. *Syn.:* Coppice. *Distr.:* Taynton, uncommon; trees have been seen with characters intermediate between Coppy and Yellow Huffcap.

Coppice .. .. see Coppy.

Cowslip .. .. *Distr.:* Newent, uncommon.

Cumber .. .. see Lumber ; name reported to Durham from Huntley.
Devil .. .. .. *Distr.:* East Dean, common ; used for various pears.
Devildrink .. .. see Devil ? *Distr.:* Westbury, Littledean, common. and see Heydon ? *Distr.:* Westbury, Littledean, common.
Drunkers .. .. see Heydon. *Distr.:* East Dean, frequent.
Dymock Red .. .. see Thurstons Red. *Distr.:* Newent, uncommon ; a very common name more often used for a local apple and a plum.
Early Blet .. .. *Distr.:* Longhope, East Dean, uncommon ; ripens August.
Early Hay Pear .. *Syn.:* Hay Pear. *Distr.:* Newent, uncommon.
Early Treacle .. .. *Syn.:* Treacle ? *Distr.:* Kempley, frequent.
Eye .. .. .. D. *Distr.:* Newent ? ; identification not yet certain but not identical with High.
Flakey Bark .. .. D. *Distr.:* Taynton, uncommon.
Ford's Green Huffcap see Hillend Green. *Distr.:* Newent, uncommon, probably Durham's name.
Forrest Pear .. .. *Distr.:* Newent, uncommon.
Gennet .. .. .. *Distr.:* Newent, Oxenhall, uncommon ; name given to several types, more common in Herefordshire.
*Gin .. .. .. D. *Distr.:* Newent, Taynton, Upleadon, Rudford, common ; evidence to support local belief that more than one type goes under this name.
Grandfather Tum .. *Distr.:* Dymock, uncommon ; fruit and leaf resemble Tumper but are larger.
*Green Huffcap .. see Yellow Huffcap. *Distr.:* Oxenhall, Longhope, Littledean, common.
*Green Horse .. .. *Syn.:* Horse Pear ? *Distr.:* most parishes, common.
*Green Longdon .. *Syn.:* Brown Longdon, Old Fashioned Longdon, Russet Longdon, Longdon (Longlands). *Distr.:* most parishes, frequent ; often confused with Red Longdon and Winnals Longdon.
Gregg's Pit .. .. *Distr.:* Dymock, uncommon.
Hampton Rough .. *Syn.:* Roughs. *Distr.:* Blaisdon, uncommon ; not either of types described by Durham.
Hastings .. .. *Distr.:* Bromsberrow, uncommon ; interesting due to the age of this variety, once used for dessert.
Hawfield .. .. see Oldfield. *Distr.:* Tirley, uncommon.
Hay Pear .. .. see Early and Late Hay Pears.
Hellens Green .. .. D. *Distr.:* Dymock, uncommon.
Heydon .. .. *Syn.:* Devildrink ?, Drunkers. *Distr.:* Littledean, Westbury, common.
High .. .. .. *Distr.:* Kempley, common.
Hillend Green .. .. *Syn.:* Ford's Green Huffcap. *Distr.:* Tibberton, Rudford, frequent.
Holmer .. .. .. H & B, D. *Syn.:* Cluster Top. *Distr.:* Dymock, uncommon.
*Horse Pear .. .. see Green Horse ? *Distr.:* most parishes ; a general term used to refer to several green pears.
*Huffcap.. .. .. see Yellow Huffcap ; also used for Brown, Black, Red, other less widely known Huffcaps and Rock.
Judge Amphlett .. *Distr.:* Dymock, uncommon ; distributed by Long Ashton.
Kings Arms .. .. see Yellow Huffcap. *Distr.:* Newent, uncommon.
*Knapper .. .. *Distr.:* Taynton, Tibberton, Huntley, Longhope, Newent, common ; one of the earliest ripening varieties.
Knight's Monarch .. *Distr.:* East Dean, Littledean, common ; general purpose pear.
Late Hay Pear .. *Syn.:* Hay Pear. *Distr.:* Newent, uncommon.
Late Treacle .. .. *Distr.:* Newent, uncommon.
Lintot .. .. .. see New Meadow. *Distr.:* Dymock, Bromsberrow, uncommon. A Worcestershire name.
*Longdon .. .. *Syn.:* Longland(s) ; see Red, Green, White, Yellow, Winnals and Bastard Longdons.
Longland(s) .. .. see Longdon. *Distr.:* Newent, common.
*Lumber .. .. D. *Syn.:* Cumber, Steelyard Balls, Steelyer Balls, Swaycots.
(Lumber Reds) *Distr.:* Longhope, Westbury, Blaisdon, Minsterworth, Taynton, Huntley, common ; general purpose pear.
*Malvern Hill(s) .. see Moorcroft.
Merrylegs .. .. *Distr.:* Longhope, Blaisdon, East Dean, uncommon.
*Moorcroft .. .. H & B, D. *Syn.:* Malvern Hill(s), Choke Pear (Chokers), Stinking Bishop. *Distr.:* all parishes, common.
Mumblehead .. .. D. *Distr.:* Newent, uncommon ; often used as a loose term for perry.
Murrel .. .. .. *Distr.:* Newent, Oxenhall, uncommon.
*Nailer .. .. .. *Syn.:* Billy Williams. *Distr.:* Blaisdon, Longhope, Newent, Oxenhall, common.

Napper .. .. .. see Knapper.
New Meadow .. .. H & B, D. *Syn.:* Yokehouse, Lintot. *Distr.:* Taynton, Dymock, uncommon.
Offield .. .. .. see Oldfield.
Old Fashioned Longdon see Green Longdon. *Distr.:* Bromsberrow; more frequent in Worcestershire.
Old Squash .. .. see Arlingham Squash. *Distr.:* Westbury, Minsterworth, common.
Old Taynton Squash .. see Arlingham Squash. *Distr.:* Taynton, Ashleworth, uncommon.
*Oldfield .. .. K, H & B, D. *Syn.:* Ollville (Oleville), Offield, Awrel, Hawfield. *Distr.:* all parishes, common; several inferior pears go under this name besides the true Oldfield.
*Ollville (Oleville) .. see Oldfield.
Painted Lady (Painted Pear) .. .. see Blakeney Red? *Distr.:* Newnham, uncommon; report from a local authority, interesting because the name has a much longer history than Blakeney Red.
Parsonage .. .. H & B. *Distr.:* Kempley, uncommon.
Phelp's Bergamot (Bergamy) .. *Distr.:* Taynton, Longhope, frequent; general purpose pear.
*Pine .. .. .. H & B, D. *Distr.:* Taynton, Dymock, uncommon, and see Pint. *Distr.:* most parishes, except those near Severn.
Pint .. .. .. H & B, D. *Syn.:* Pine. *Distr.:* Dymock, uncommon.
Port .. .. .. see White Longdon. *Distr.:* Dymock, uncommon.
*Red Horse .. .. see Red Pear.
Red Huffcap .. .. *Syn.:* Huffcap, Uffcap (Uffcup). *Distr.:* Blaisdon, uncommon. and see Rock. *Distr.:* Newent.
*Red Pear .. .. H & B, D. *Syn.:* Red Horse, Aylton Red. *Distr.:* all parishes north of Newent.
*Red Longdon .. .. K, H & B, D. *Syn.:* Brockle (Brockull), Cider Pear, Longdon (Longlands). *Distr.:* most parishes, uncommon; once very popular near the Severn.
Rock .. .. .. H & B, D. *Syn.:* Brown, Red or Black Huffcap, Uffcap (Uffcup). *Distr.:* Bromsberrow, uncommon.
Bosbury Scarlet .. *Distr.:* Bromsberrow, uncommon.
Rough(s) .. .. see Hampton Roughs. *Distr.:* Churcham, uncommon, and see Chaxhill Rough.
Russet Longdon .. see Green Longdon. *Distr.:* Newent, common.
Sack .. .. .. D. *Distr.:* Newent, Oxenhall, common.
Squash Pear .. .. see Arlingham, Taynton, Staunton Squashes; sometimes used for other early squash types.
Staunton Squash .. H & B. *Syn.:* Squash Pear. *Distr.:* Corse, Hasfield, uncommon.
Steelyard Balls .. see Lumber. *Distr.:* Huntley, Taynton, uncommon.
Steelyer Balls .. .. see Lumber. *Distr.:* Huntley, Taynton, Longhope, common.
Stinking Bishop .. see Moorcroft. *Distr.:* Highnam, Newent, uncommon.
Swan Egg (Swan) .. *Distr.:* Maisemore, Ashleworth, Hasfield, uncommon; general purpose pear.
Swaycots .. .. see Lumber. *Distr.:* Blaisdon, Westbury, uncommon.
Taynton Squash .. K ?, H & B ?, D. *Syn.:* Squash Pear. *Distr.:* Dymock, and K ?, H & B ? *Syn.:* Squash Pear. *Distr.:* Taynton, uncommon.
*Thorn .. .. .. H & B, D. *Distr.:* all parishes north of Churcham.
Thurston's Red .. H & B, D. *Syn.:* Dymock Red, Billy Thurston. *Distr.:* Blaisdon, Longhope, East Dean, common.
Treacle .. .. .. see Early Treacle? *Distr.:* many parishes; probably used for several sweet pears.
Tumper (Tum, Tom, Tump) .. .. D. *Distr.:* Huntley, Newent, Longhope, common.
Turners Barn .. .. *Syn.:* Barn. *Distr.:* Newent.
Uffcap (Uffcup) .. see Huffcap.
White Bache (Beech) .. D. *Syn.:* Bache (Beech) White. *Distr.:* Oxenhall, Kempley, uncommon.
White Longdon (Longland(s)) .. H & B. *Syn.:* Longdon (Longland(s)), Bastard Longdon, Port. *Distr.:* Blaisdon, Newent, Corse, uncommon.
White Moorcroft .. *Distr.:* Kempley, uncommon; some of the largest perry trees examined.
White Squash .. .. see Staunton Squash. *Distr.:* Tirley, Chaceley, uncommon.
Winnals Longdon .. H & B, D. *Syn.:* Longdon, Longland(s). *Distr.:* Dymock, uncommon.
*Yellow Huffcap .. *Syn.:* Huffcap, Uffcap (Uffcup), Chandos Huffcap, Yellow Longdon (Longland(s)), Kings Arms, Green Huffcap, Black Huffcap. *Distr.:* Forthampton, Chaceley, common.

Yellow Longdon (Longland(s))	..	see Yellow Huffcap. *Distr.:* Newent, uncommon.
Yokehouse	..	see New Meadow. *Distr.:* Taynton, uncommon; not to be confused with Worcestershire name Yokeing House.
Young Heydon	..	*Distr.:* East Dean, uncommon; similar to Blakeney.

Acknowledgments.

The author is indebted to the many farmers, perry makers and others who have made the investigation possible through their co-operation and enthusiasm to assist in the project.

Grateful thanks are expressed to Mr. E. Ball of Messrs. H. P. Bulmer and Co. for his valuable advice, and to Mr. T. A. C. Mason of Kingsland, for the facilities allowed at the Broxwood Perry Museum.

REFERENCES.

(1) Knight, T. A. (1811). *Pomona Herefordiensis.*
(2) Hogg, R. and Bull, H. G. (1876-1885). *The Herefordshire Pomona.* Jakeman & Carver, Hereford.
(3) —— —— —— (1886). *The apple and pear as vintage fruits.* Jakeman & Carver, Hereford.
(4) Durham, H. E. (1924). The beauty and use of the vintage pear. *J. Roy. Hort. Soc.*, **49**, 157-166.

PERRY PEARS AND THEIR CHARACTERS: I.

By R. R. WILLIAMS.

These illustrated descriptions of perry pears are intended to facilitate the identification of varieties and to indicate the particular variety considered to be the true representative of a given name. The information given below concerns only the characteristics of greatest diagnostic value; thus fruit characters have been given in detail, together with a few important features of the tree, flower and leaf.

The synonyms included are those with a wide distribution; the more local names will be found in "A Survey of Perry Pears in the West Midlands" (1). The terms used to indicate the fruit shape are explained in Fig. 1. The fruit description covers the variation found in typical samples from normal trees. In exceptional seasons the harvesting period may extend outside the period given. The milling time refers to fruit bagged immediately after it is shaken; if pears are left lying in the grass then the milling period may be extended. The leaf description refers to the third or fourth leaf produced in the rosette surrounding next year's flower bud on a non-fruiting spur. The figures given with each description contain drawings of typical fruits in longitudinal section, together with a flattened spur leaf. The typical winter appearance of mature trees is illustrated by photographs.

Barland.

Fruit: 31–52 mm. long, 38–51 mm. diameter. Shape turbinate or round. Stalk 25–32 mm.; rather slender, often showing patches of green; may be connected to fruit by a fleshy lip or continuous with fruit. Stem basin absent or very shallow. Eye basin absent or slight. Calyx open. Sepals touching at base and often swollen; stamens attached at base of sepals. Skin green or yellow; russet around stem, more around eye, lenticels numerous, inconspicuous; scab invariably present, sometimes severe. Core has axial sac well defined; seeds black. Flesh has some stone cells around core. Taste juicy, sweet, astringent; possesses strong aroma. Harvest 4th week September–1st week October. Milling period up to 3 days after harvesting. Cropping poor.

Tree: Large. Head tall; the trunk is usually continued as a few large upright limbs; branches rather small, wide angled.

Flower: Flowering period late mid-season. Flower buds red. Blossom very large; petals pink, open a long time before anthers burst; pollen germination very poor.

Leaf: Stalk 39–53 mm. Blade 50–57 mm. long, 38–50 mm. wide; obovate or broadly elliptical, tip acuminate, base rounded or slightly tapering; serrations absent.

General notes: Solitary Barland trees, the last vestige of old perry orchards, are a characteristic feature of the West Midlands. The characters of this variety suggest that it is a triploid, and its present poor cropping may be attributable to lack of suitable cross pollination. The variety was formerly considered a heavy cropper.

Barnet.

Fruit : 43–57 mm. long, 38–51 mm. diameter. Shape turbinate, inclined to be elliptical. Stalk 28–35 mm. ; stiff, often connected to fruit by a fleshy lip. Stem basin absent. Eye basin shallow or well defined. Calyx upright or slightly reflexed. Sepals free, stamens attached just within base of sepals ; sepals and stamens often green and fleshy. Skin green or yellowish green ; flush slight to heavy, orange red, sometimes streaked, russet more or less covers fruit, often scaly ; lenticels not conspicuous ; scab rarely present. Core has axial sac sometimes ill defined ; seeds dark brown ; frequently only four carpels. Flesh has few stone cells around core. Taste sweet, soft, astringent ; possessing an aroma. Harvest 1st–2nd week October. Milling period 1–3 weeks after harvesting. Cropping good, may be heavier in alternate years.

Tree : Medium to large. Head with acute crotches, long branches with spreading habit resulting from heavy crops ; conspicuous spurs consisting largely of bourse shoots.

Flower : Flowering period late. Inflorescence densely pubescent. Petals yellowish white.

Leaf : Stalk 25–45 mm. Blade 50–63 mm. long, 38–57 mm. wide ; broadly elliptical, tip acuminate, base rounded or slightly cordate ; pronounced serrations.

General notes : A variety of considerable merit ; the fruit is fairly large ; it shakes easily, and cropping is consistent.

Blakeney Red.

Fruit : 49–62 mm. long, 49–59 mm. diameter. Shape pyriform or turbinate. Stalk 26–38 mm. ; slender. Stem basin small, narrow and deep. Eye basin well defined. Calyx open or reflexed. Sepals touching or joined ; stamens attached at base of sepals. Skin yellow, flush heavy, sometimes streaked ; russet spreads from eye over part of check ; lenticels numerous, small, rarely large, conspicuous. Core has axial sac well defined, usually large ; seeds generally light brown ; carpel walls usually stained with brown patches. Flesh has some stone cells around core. Taste juicy, sweet, astringent, possessing an aroma. Harvest 4th week September–2nd week October. Milling period up to 7 days after harvesting. Cropping very heavy.

Tree : Medium to large. Very acute crotches, numerous upright limbs in young trees which later spread through cropping.

Flower : Flowering period mid-season. Flower buds white.

Leaf : Stalk 39–57 mm. Blade 63–89 mm. long, 44–57 mm. wide, elliptical, tip acuminate, base rounded ; serrations indefinite.

General notes : Widely planted about 70 years ago as a dual purpose pear, for culinary fruit and perry. The most reliable cropper among the common varieties. Its reputation as a perry pear is subject to much controversy. The type of soil in which the trees are grown and the period of milling are widely considered to decide the quality of the perry, which shows wide variation.

Butt.

Fruit : 44–51 mm. long, 42–51 mm. diameter. Shape turbinate or rarely pyriform. Stalk 23–30 mm., slender, often green patches ; may be connected to fruit by a small fleshy lip. Stem basin absent. Eye basin slight or absent. Calyx open or reflexed. Sepals joined, stamens attached at base of sepals. Skin yellow or greenish yellow, russet around stem and eye ; lenticels generally small and inconspicuous, but often large and conspicuous on russet, resembling numerous small scab infections ; scab may be present. Core has axial sac well defined, usually partly filled ; seeds black. Flesh has stone cells around core, often has a yellow tinge. Taste sweet, very astringent, no aroma. Harvest 1st–2nd week November. Milling period 4–10 weeks after harvesting. Cropping heavy but often biennial.

Tree : Medium to large. Narrow-angled crotches, limbs spreading due to crops, heavy conspicuous spur systems on long branches.

Flower : Flowering mid-season. Flower buds white.

Leaf : Stalk 33–64 mm. Blade 38–57 mm. long, 44–51 mm. wide ; broadly elliptical, tip acuminate, base rounded ; some serrations.

General notes : One of the most popular varieties grown today. Heavy crops of medium sized pears are usual and the fruit is often left lying on the ground for months until it is required. There is a common saying, " Gather your Butts one year, mill them the next and drink the year after." No difference has been noted between Butt and Norton Butt.

Moorcroft.

SYN. MALVERN HILLS.

Fruit : 44–60 mm. long, 43–57 mm. diameter. Shape turbinate, sometimes pyriform. Stalk 24–31 mm., conspicuous lenticel spots, sometimes green patches, may be connected to fruit by a fleshy lip. Stem basin absent or rarely very slight. Eye basin wide and shallow. Calyx upright if present. Sepals free or touching ; stamens attached at base of sepals. Skin yellow or yellowish green ; russet both ends or only around eye ; lenticels numerous, large, off-white, conspicuous ; scab often severe. Core has variable axial sac ; seeds black. Flesh has few stone cells around core. Taste juicy, melting, sweet, astringent, possesses an aroma. Harvest 3rd–4th week September. Milling period up to 2 days after harvesting. Cropping light to medium.

Tree : Large. Acute angled crotches, usually a small number of long upright limbs.

Flower : Blooms early mid-season. Flower buds tinged with pink. Blossom white ; styles twisted and bent, much longer than stamens ; king flowers irregular, 5–10 sepals and petals.

Leaf : Stalk 37–51 mm. Blade 50–69 mm. long, 26–44 mm. wide ; elliptical to ovate, tip acuminate or acute ; base rounded, serrations absent or few.

General notes : Very widely grown and very popular for perry making. The fruit is severely attacked by scab in some years. The pears ripen over rather a long period and are difficult to shake. Not to be confused with the variety White Moorcroft.

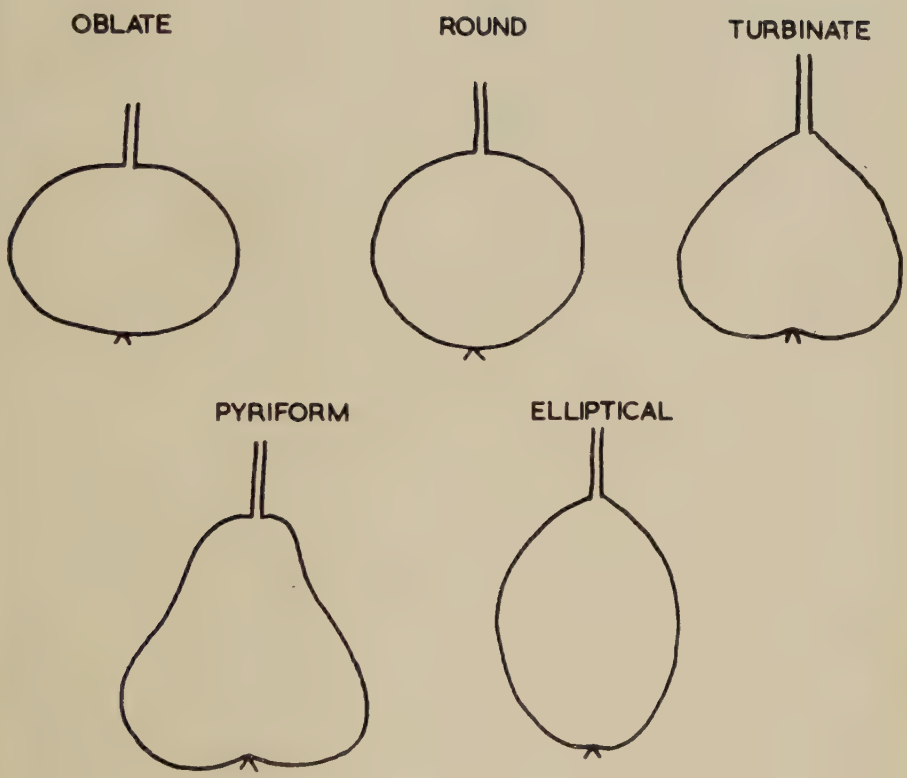
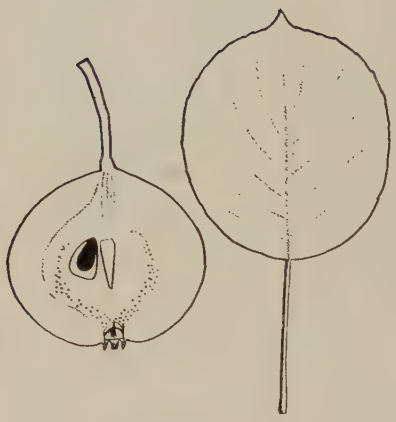
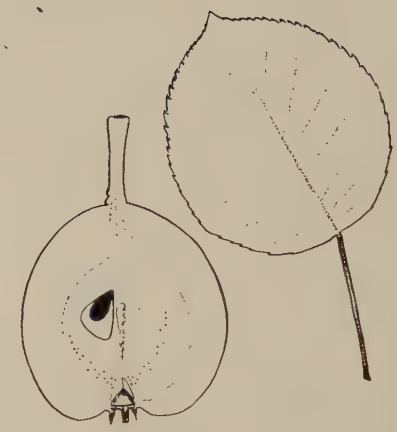


Fig. 1. The range of fruit shape in perry pears.



BARLAND.



BARNET.

BLAKENEY RED.

BUTT.

Fig. 2.

BARLAND.

BARNET.

BLAKENEY RED.

BUTT.

Fig. 3.

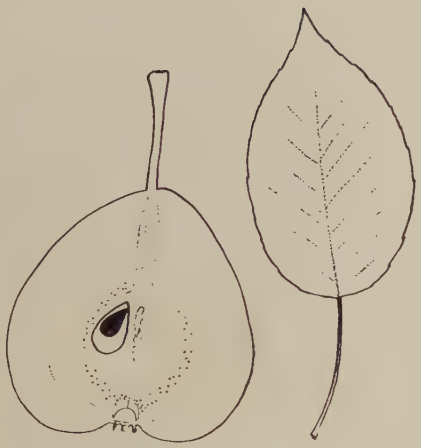
MOORCROFT.

OLDFIELD.

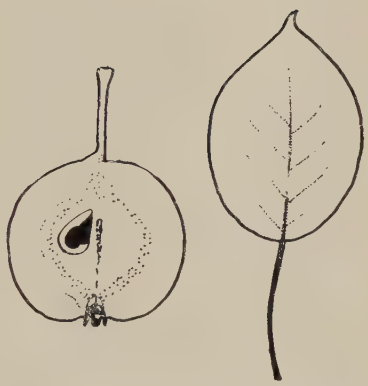
PINE.

RED PEAR.

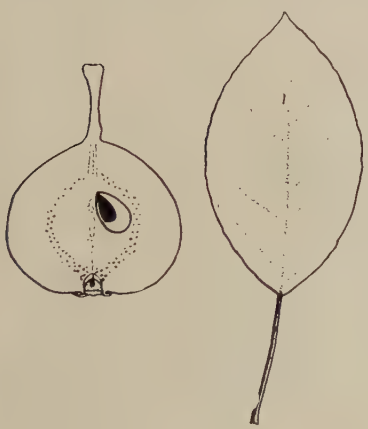
Fig. 1.



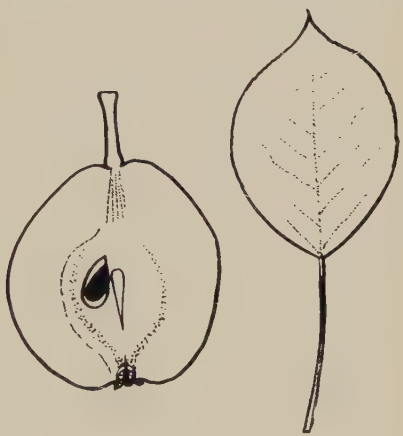
MOORCROFT.



OLDFIELD.

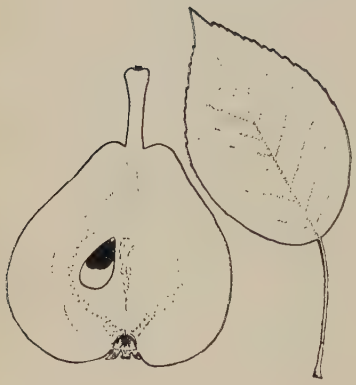


PINE.



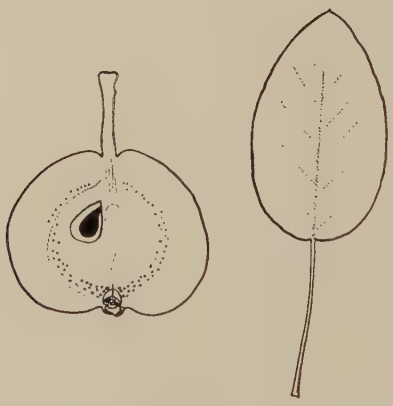
RED PEAR.

Fig. 5.



RED LONGDON.

TAYNTON SQUASH.



ROCK.

Fig. 6.

RED LONGDON.

TAYNTON SQUASH.

ROCK.

Fig. 7.

WINNAL'S LONGDON.

YELLOW HUFFCAP.

Fig. 8.

WINNAL'S LONGDON. YELLOW HUFFCAP.

Fig. 9.

Oldfield.

SYN. OLLEVILLE.

Fruit : 33–43 mm. long, 38–48 mm. diameter. Shape oblate, round or rarely turbinate. Stalk 19–26 mm. ; slender ; often attached to fruit by a fleshy lip. Stem basin absent. Eye basin wide and shallow. Calyx upright. Sepals free, stamens attached some distance below the base of the sepals. Skin green to yellow ; russet both ends ; lenticels numerous, variable size, conspicuous ; scab often severe. Core has filled axial sac or none ; seeds black ; large carpels. Flesh has few stone cells around core. Taste juicy, acid, astringent ; aroma fugitive, suggestive of apples. Harvest 3rd–4th week October. Milling period 3–6 weeks after harvesting. Cropping good in favoured localities.

Tree : Medium to small. Wide angled crotches ; old trees often consist of only a few small branches following severe attacks of canker.

Flower : Blooms early mid-season. Flower buds white.

Leaf : Stalk 26 38 mm. Blade 50–57 mm. long, 32–45 mm. wide ; elliptical rarely obovate ; tip long acuminate, base rounded ; serrations absent or irregular.

General notes : A variety which was widely planted for vintage bottled perry. Healthy trees are unusual except in a few favoured districts. Some trees have shown different leaf and tree characters but fruits identical with the true type.

Pine.

Fruit : 31–44 mm. long, 31–44 mm. diameter. Shape turbinate approaching round or oblate. Stalk 16–22 mm. ; swollen at the abscission point, may be lumpy, often largely green, generally joined to the fruit by a fleshy lip. Stem basin absent. Eye basin shallow, sometimes absent. Calyx reflexed. Sepals tubular or joined ; stamens attached at the base of sepals. Skin yellowish green or yellow ; occasional flush, orange red, streaked ; russet around stem and eye, often extending over cheek ; lenticels numerous, variable, merging into russet ; no scab. Core has axial sac absent or filled ; seed black. Flesh has stone cells around core ; may be yellowish when mature ; hard. Taste juicy, moderate to high astringency ; possesses an aroma. Harvest 3rd–4th week October. Milling period up to 4 weeks after harvesting. Cropping biennial but good.

Tree : Small. Acute angled crotches, numerous stiff upright limbs opening a little due to crops ; complex spur systems very prominent.

Flower : Blooms early mid-season. Flower buds have slight tinge of pink. Inflorescence mounted on a short stalk, heavily pubescent. Blossoms have stigmas much longer than stamens, twisted.

Leaf : Stalk 25–38 mm. Blade 50 63 mm. long, 26–39 mm. wide ; elliptical, tip acute, base tapering ; serrations absent or irregular.

General notes : Widely grown but rarely in large numbers. The name Pine is more commonly used for the Pint pear.

Red Pear.

SYN. RED HORSE.

Fruit : 39–49 mm. long, 42–51 mm. diameter. Shape turbinate. Stalk 14–19 mm. ; medium to stout ; often swollen at the point of attachment to the fruit. Stem basin small, narrow. Eye basin slight, consisting largely of irregular shoulders. Calyx open or strongly reflexed. Sepals free or touching, small ; stamens attached at the base of sepals. Skin yellow or greenish yellow ; flush almost complete, very strong around eye ; russet around stem, more around eye spreading over cheek ; lenticels numerous, large, brown or off-white, sometimes conspicuous; some scab usual. Core has variable axial sac ; seeds light brown. Flesh has few prominent stone cells. Taste juicy, sweet, usually astringent ; possesses an aroma. Harvest 1st–3rd week October. Milling period up to 3 weeks after harvesting. Cropping good often biennial.

Tree : Medium to small. Crotches fairly wide angled, trees often rather tall, thick spurs.

Flower : Flowering period late. Flower buds pink. Inflorescence has little pubescence.

Leaf : Stalk 18–41 mm. Blade 44–60 mm. long, 28–41 mm. wide ; obovate to elliptical ; tip acute or short acuminate, base tapering or rounded ; serrations slight or absent.

General notes : A very old variety still popular in Herefordshire and Worcestershire. It has not proved possible to differentiate between Red Pear and Aylton Red ; this description covers both.

Red Longdon.

Fruit : 48–60 mm. long, 51–61 mm. diameter. Shape turbinate or pyriform. Stalk 15–24 mm. ; stout. Stem basin slight, sometimes absent. Eye basin shallow, rarely has shoulders. Calyx upright or reflexed. Sepals free, sometimes pubescent ; stamens attached at the base of sepals. Skin green or greenish yellow ; flush strong, red or orange red, spreading from eye ; russet around stem, more around eye spreading on to cheeks ; lenticels numerous, large, light coloured, conspicuous, especially on flush; usually some scab. Core generally has well defined axial sac but it may be filled ; seeds brown to black. Flesh has stone cells prominent below eye. Taste juicy, sweet, slightly astringent, possesses an aroma. Harvest 1st–2nd week October. Milling period up to 3 weeks after harvesting. Cropping regular but not heavy.

Tree : Medium size. Acute angled crotches, upright growth, branches taper abruptly into twiggy growth.

Flower : Flowers mid-season. Flower buds white. Very pale anthers.

Leaf : Stalk 25–38 mm. Blade 52–69 mm. long, 32–44 mm. wide ; elliptical, variable ; tip acute, rarely short acuminate ; base broadly rounded to tapering ; some serrations.

General notes : An old variety considered by T. A. Knight to be nearing the end of its useful life. Now represented by scattered trees. Often confused with the other Longdons to which it shows no resemblance.

Taynton Squash.

Fruit : 39–45 mm. long, 46–52 mm. diameter. Shape oblate or turbinate. Stalk 20–27 mm. ; often connected to the fruit by a fleshy lip. Stem basin is absent or very slight. Eye basin wide, shallow, well defined or slight. Calyx open or upright, rarely reflexed. Sepals free or touching, may be mainly green ; stamens attached within the base of sepals. Skin greenish yellow ; sometimes a light flush ; russet around stem, more around eye, spreading on to cheek ; lenticels numerous, small, sometimes coalescing into patches, conspicuous ; scab usual, often severe. Core large and well defined, has axial sac ; seeds dark brown or black. Flesh sparse, has stone cells around core. Taste juicy, sweet, astringent, possesses an aroma. Harvest 3rd–4th week September. Milling period up to 2 days after harvesting. Cropping heavy usually biennial.

Tree : Medium to large. Acute angled crotches, limbs spread from cropping, branches of thin twiggy wood often pendular.

Flower : Flowers early. Flower buds tinged with pink.

Leaf : Stalk 38–45 mm. Blade 44–55 mm. long, 34–52 mm. wide ; elliptical, tip acuminate, base rounded to slightly cordate ; always serrated.

General notes : A very old variety that is now uncommon. While this is the type generally known as Taynton Squash it is not identical with the trees seen in Taynton parish, its reputed home. The leaf characters are the best diagnostic feature.

Rock.

SYN. BROWN HUFFCAP.

Fruit : 35–43 mm. long, 41–48 mm. diameter. Shape turbinate or oblate. Stalk 15–22 mm. ; rather stout ; often patches of green ; commonly connected to the fruit by a fleshy lip. Stem basin slight, deep and narrow ; or absent. Eye basin wide and well defined. Calyx tightly closed or slightly open. Sepals free or touching, sometimes heavily pubescent ; stamens attached at the base of sepals. Skin green, greenish black or greenish yellow ; flush slight, rarely heavy, yellowish orange to red ; russet around stem, more around eye spreading on to cheek ; lenticels numerous, sometimes large, especially on russet, nearly white ; usually some scab. Core generally has axial sac well defined, always filled ; seeds dark brown or black. Flesh has very prominent stone cells in a thick ring ; usually tinged with green or yellow in contrast to the white core ; very hard. Taste rough, acid, very astringent, no appreciable aroma. Harvest 4th week October–1st week November. Milling period up to 8 weeks after harvesting. Cropping regular, light to medium, sometimes biennial.

Tree : Medium size. Very wide angled crotches, spreading, frequently horizontal branches ; thin twiggy wood often severely cankered. The bark on the trunk and main limbs is deeply striated longitudinally.

Flower : Flowering period very late. Flower buds white. Inflorescence densely pubescent.

Leaf : Stalk 28–47 mm. Blade 43–63 mm. long, 26–36 mm. wide ; elliptical, inclined to ovate, tip obtuse, rarely acute, base rounded inclined to cordate ; no serrations ; pubescent.

General notes : This variety is believed to be only 150 years old and Rock trees predominate in many younger orchards. The fruit usually hangs in clusters of 5–9 fruits. The skin has a characteristic hard shiny appearance, is finely puckered or wrinkled and often marked with black scratches or black surface bruises. The leaf shape is the best diagnostic character, as several types have been planted which have apparently identical fruit but pronounced ovate or round leaves. The fruit will not mature during storage but slowly turns black with a dry rot. The high gravity of Rock juice and its intense astringency are renowned.

Winnal's Longdon.

Fruit : 51–62 mm. long, 38-50 mm. diameter. Shape pyriform. Stalk variable, 13–25 mm. ; often green adjacent to fruit. Stem basin absent or slight. Calyx strongly reflexed. Sepals free, long, purple colour ; red stamens attached at the base of sepals. Skin greenish yellow or yellow ; a heavy, rarely slight, red flush often streaked ; slight to heavy bloom ; russet around stem, more around eye ; lenticels numerous, small, light brown, conspicuous ; no scab. Core has axial sac large and clearly defined, carpel walls may break down to give open cells ; seeds dark brown or black. Flesh has weak ring of stone cells. Taste juicy, sweet, astringent, some aroma. Harvest 1st–2nd week October. Milling period up to 7 days after harvesting. Cropping heavy, sometimes biennial.

Tree : Medium to large. Sturdy upright limb system with numerous small branches giving a well shaped tree.

Flower : Flowering period mid-season. Flower buds white. Blossom with more than 5 sepals and petals common. Very pale anthers.

Leaf : Stalk 38–45 mm. Blade 62–72 mm. long, 32–40 mm. wide ; elliptical, tip acute, base rounded, serrated.

General notes : Grown between Ross and Tewkesbury. The fruit should be harvested before it commences to drop in great quantity. Many fruits have an irregular eye with 6–9 sepals. Often confused with the other Longdon pears, particularly Green Longdon, though there is no resemblance.

Yellow Huffcap.

SYN. HUFFCAP.

Fruit : 41 51 mm. long, 35 45 mm. diameter. Shape elliptical. Stalk 14–22 mm., thick, swollen at both ends, often lumpy; rarely slender. Stem basin small and narrow or absent. Eye basin has a raised eye, often with shoulders which may contain a small narrow basin. Calyx upright or rarely slightly reflexed. Sepals free ; stamens attached below the base of the sepals. Skin green, yellow or yellowish black ; no flush ; russet, often scaly, around stem and eye, often spreading on to cheeks ; lenticels numerous, usually large, conspicuous, brown and corky merging into russet ; scab generally absent. Core has axial sac but rarely well defined, usually partially filled ; carpel walls may break down to give open cells ; seeds black. Flesh has few stone cells ; often slightly yellow. Taste juicy usually very sweet, slight to moderate astringency ; possesses an aroma. Harvest 1st–3rd week October. Milling period up to 7 days after harvesting. Cropping very heavy, often biennial.

Tree : Large. Fairly wide angled crotches, large spreading limbs, rather twiggy branches with numerous small spurs.

Flower : Flowering period early mid-season. Flower buds tinged with pink.

Leaf : Stalk 30–48 mm. Blade 59–74 mm. long, 29–41 mm. wide ; elliptical, tip acute, base tapering ; serrated.

General notes : A variety of high repute. The fruit must be shaken just before it is ripe or it may rot on the tree. There are numerous other Huffcaps, some very similar, but the fruit dimensions given above are diagnostic. Other pears of wide distribution are also called Yellow Huffcap.

Acknowledgments.

The author is indebted to the farmers who have afforded facilities for this investigation. Thanks are also due to Mr. G. M. Jones, A.R.P.S., who made the photographic records.

REFERENCE.

(1) Williams, R. R. (1954). A survey of perry pears in the West Midlands. *Ann. Rep. Long Ashton Res. Sta.*, 1953, 64.

THE PROPAGATION OF GOOSEBERRIES: I. SOME FACTORS INFLUENCING THE ROOTING OF HARDWOOD CUTTINGS.

By BARBARA A. RAKE.

Introduction.

Although the rooting of gooseberry cuttings on a small scale does not appear to present any problems, there have been frequent reports from commercial nurserymen of bad results, particularly in recent years. The high price at which gooseberry bushes are offered compared with that of other soft fruits propagated by the same method is a fair indication of the difficulties experienced in raising them economically. The production of 50% of well-rooted cuttings is usually considered satisfactory, but few nurserymen manage to reach this figure and may often obtain only 10%.

In the normal commercial method for the preparation of gooseberry cuttings (1), strong, one-year old shoots are cut to a length of 10–12 inches with a sharp knife, the basal cut being made just below a bud. The tip of the shoot is cut back to a well-developed bud, and all buds and spines except the top four are removed, unless the bush is to be grown on the stool principle, when the buds and spines are left intact. It is important that the cuttings should be planted or heeled-in as soon as possible after removal from the parent bush, and poor results are sometimes attributable to failure to do this. Often the task of preparing gooseberry cuttings is reserved as a wet weather job and, in the event of not being completed at one time, the unprepared cuttings are left around in a shed until the next wet spell or until labour is available.

In 1951 experiments were begun to examine some of the factors involved in the rooting of hardwood cuttings of gooseberries. Attention was first paid to the effect of variations in the preparation of the cutting. Later experiments will deal with the condition and source of the cuttings, the preparation of the cutting bed and the treatment of the cuttings after insertion.

The present report is the first progress report to be published on this work.

Experimental Methods.

The cuttings were laid out in blocks containing randomised treatments. Each treatment unit consisted of a row of cuttings (15 per plot in 1951 and 12 per plot in 1952; in the 1952 experiment the two end cuttings were treated as guards, and were disregarded in the records). Planting and subsequent cultivations were carried out in the normal commercial manner.

At the end of the following growing season records were taken of the number of cuttings then alive. Owing to the fact that many cuttings were still alive but had made little growth, records were also made of the vigour, expressed in categories 0–10 per plot; 0 indicating plots on which cuttings were still alive but had not grown, and 10 indicating plots of unusually vigorous cuttings: a score of 5 for vigour was considered satisfactory. No direct measurements were made on the roots as it was thought that the figures for

vigour taken at the end of the growing season gave a sufficiently good indication of the amount of root. Furthermore, from the nurseryman's point of view, the size of the bush is the main criterion of saleable value.

As the results were expressed in percentages, angular transformation was carried out on the figures before their significance was determined by analysis of variance.

1951 Experiment.

This was a factorial experiment consisting of 2 blocks of the 32 treatments obtained by combination of the factors listed below; there were thus 16 replicates of each planting date and 32 replicates of the other factors.

(1) *Variety.* The varieties Keepsake and Leveller were used.

(2) *Time of taking and planting cuttings.* Cuttings were taken and planted at four different dates between the end of August and the end of November. The first cuttings taken were semi-ripened, but by September the wood was fairly well ripened.

(3) *Leaves.* The leaves on the four upper nodes were removed in half the treatments, and retained in the other half; all other leaves on the cuttings were always removed with the buds. Practically no leaves were present on the cuttings at the November planting and any remaining soon dropped off.

(4) *Type of shoot.* The rooting ability of sucker shoots from the base of the bush was compared with that of less-vigorous one-year-old shoots with a basal heel, taken from the branch framework.

The cuttings, prepared with a knife, were 9 inches long and were disbudded (removing buds, leaves and spines) leaving only four buds at the top. They were planted within 48 hours of preparation in a grip 6 inches deep, 6 inches apart, in rows 3 feet apart.

1952 Experiment.

In this experiment there were 10 different treatments, all of which were replicated 4 times on two different soils, using the varieties Leveller, Keepsake and Careless. The experiment was designed to investigate the effect of :—

(1) *The retention of leaves* along the whole length of the shoot as compared with leaves at the upper four nodes only.

(2) *The retention of buds* on the lower portion of the cutting. The removal of the lower buds from gooseberry cuttings is usually considered necessary in order to form a "leg" on which the mature bush is grown, and to prevent suckering. It was thought that considerable labour might be saved in the preparation of the cuttings if the buds were left on, any sucker shoots arising from them being removed when the bushes were lined out in the nursery. Buds have been reported to have a stimulating or a retarding effect on the rooting of cuttings of different species according to the time of year or phase in the periodic development of the parent plant at which the cuttings are taken and planted (2). The effect of bud retention was investigated at two planting times.

(3) *Removal of the shoot tip.* The shoot tip is usually removed, but some nurserymen plant gooseberry cuttings intact, leaving the shoot tip on the cutting until bud-burst, when it is cut back to a strong bud.

(4) *Time of taking and planting cuttings.* The cuttings were taken and planted at two different times : early August (semi-hardwood cuttings) and December (fully dormant cuttings).

(5) "*Heeling in.*" The practice of taking the cuttings in early winter during pruning time, preparing them and "heeling" them in until conditions are suitable for planting is followed in some nurseries. The effect of "heeling in" for periods of one and two months was therefore tested in this experiment.

(6) *Soil.* Soil I was a brownish-red, non-calcareous medium loam of the Worcester Series (derived from Keuper Marl), with good drainage. Soil II was a pale brownish-red non-calcareous heavy sand, colluvial in origin, over fine sand and having impeded drainage. Both sites were on ground sloping towards a small stream. Soil I, at the top of the slope, remained well drained ; soil II, at the bottom of the slope, was much wetter and often partially flooded during winter.

Details of the preparation of the cuttings in the ten different treatments are given below :—

August planting.

A. Cutting 12″ long including shoot tip ; all leaves and buds intact.
B. Cutting 12″ long including shoot tip ; leaves and buds removed from lower 6″ of cutting.
C. Cutting 12″ long including shoot tip ; all leaves removed ; buds from lower 6″ of cutting removed.
D. Cutting 12″ long including shoot tip ; all leaves removed ; all buds left on.
E. Cutting prepared by normal commercial method, removing shoot apex and leaving four buds with subtending leaves at the top.

The cuttings were planted on August 16th, having been prepared 1–3 days previously.

December planting.

F. Cutting 12″ long including shoot tip ; buds from lower 6″ removed.
G. Cutting 12″ long including shoot tip ; all buds intact.
H. Cutting prepared by normal commercial method.
J. Cutting prepared by normal commercial method in November ; "heeled in" for one month before planting.
K. Cutting prepared by normal commercial method in October ; "heeled in" for two months before planting.

Treatments F-K were planted on December 22nd, having been prepared 2–3 days previously (except for treatments J and K).

Treatments A, B, C, D, F and G were planted with the lower 6″ of the cutting below ground level, and were cut back to four visible buds at bud-burst in early March. Treatments E, H, J and K were planted with the lowest bud just above soil level.

Results.

The percentage rooting and the mean vigour score of the cuttings in the 10 different treatments of the 1952 experiment are given in Tables I and II.

TABLE I.

MEAN PERCENTAGE ROOTING OF CUTTINGS, 1952.

Variety	No. of plots	August					December				
		A	B	C	D	E	F	G	H	J	K
Leveller ..	8	85·0	71·3	38·8	52·5	21·3	68·8	26·3	67·5	58·8	72·5
Keepsake ..	8	77·5	45·0	51·3	65·0	45·0	67·5	41·3	68·8	62·5	95·0
Careless ..	8	56·3	52·5	52·5	66·3	61·3	47·5	15·0	67·5	65·0	76·3
Total ..	24	72·9	56·3	47·5	61·3	42·5	61·3	27·5	67·9	62·1	81·3

TABLE II.

MEAN SCORE FOR VIGOUR OF CUTTINGS, 1952 (MAX. 10).

Variety	No. of plots	August					December				
		A	B	C	D	E	F	G	H	J	K
Leveller ..	8	6·6	6·5	3·4	3·3	1·4	1·9	0·2	2·3	1·6	3·8
Keepsake ..	8	8·6	7·6	6·2	6·6	5·3	5·8	4·8	6·0	4·8	7·8
Careless ..	8	6·3	7·4	5·1	5·2	7·7	2·7	0·8	5·8	3·8	4·1
Total ..	24	7·2	7·2	4·9	5·0	4·8	3·5	1·9	4·7	3·4	5·2

Of the four treatments using the commercial type of cutting the best rooting percentage and vigour were shown by cuttings "heeled-in" for 2 months (K); this method is used in a number of nurseries. Cuttings "heeled-in" for only one month (J) were much less vigorous, though the rooting percentage was satisfactory and of the same order as that of cuttings planted directly in December (H); these proved particularly successful on Soil II. By contrast, direct planting of this type of cutting in August (E) gave a poor rooting percentage and only average vigour.

The August planting of unstripped cuttings (A) showed a high rooting percentage and good vigour. The 1951 experiments suggest that they would have given an even better performance if planted a few weeks later, though it is apparent from the December planting (G) that very late planting may have very adverse effects.

TABLE III.

ANALYSIS OF FACTORS IN 1952 EXPERIMENT.

Variety	Treatment	No. of Plots	Percentage Rooting	Score for Vigour
			Mean	Mean
Leveller	August (+ leaves)	24	59·2	4·8 ***
	December	24	54·2	1·4
Keepsake	August (+ leaves)	24	55·8	7·1 **
	December	24	58·3	5·5
Careless	August (+ leaves)	24	56·7	7·1 ***
	December	24	42·1	3·0
TOTAL	August (+ leaves)	72	57·2	6·3 ***
	December	72	51·5	3·3
Leveller (August)	+ leaves	16	78·1 ***	6·5
	— leaves	16	45·6	3·1
Keepsake (August)	+ leaves	16	61·3	7·9
	— leaves	16	58·1	6·4
Careless (August)	+ leaves	16	54·4	6·8
	— leaves	16	59·4	5·1
TOTAL (August)	+ leaves	48	64·6 ***	7·1 ***
	— leaves	48	54·4	4·9
Leveller	+ shoot tip	16	70·0 **	4·2 ***
	— shoot tip	16	44·4	1·8
Keepsake	+ shoot tip	16	56·3	6·7
	— shoot tip	16	56·9	5·6
Careless	+ shoot tip	16	50·0	5·1 *
	— shoot tip	16	64·4	6·7
TOTAL	+ shoot tip	48	58·8	5·3
	— shoot tip	48	55·2	4·7

*** Difference between means significant at 0·1%.
** " " " " " 1·0%.
* " " " " " 5·0%.

Although the three varieties tested did not appear to differ in their general ability to root, examination of the tables shows that varieties reacted differently to a given treatment. Thus while Careless showed up badly under treatments A, F and G, it responded better than other varieties to treatment E. This difference in varietal response might be explained by the condition of the

parent plant from which the cuttings were taken. The cuttings for Leveller and Keepsake were taken from bushes growing under similar conditions at Long Ashton : those of Careless were brought in from a distance, and were from younger bushes growing under a different environment. The difference is, however, more likely to be concerned with the inherent make-up of the variety, particularly with regard to the phasic development of the buds.

The effects of individual factors on rooting and vigour, as found in the 1951 and 1952 experiments, are discussed below.

(1) *Variety.*

TABLE IV.

THE ROOTING ABILITY OF DIFFERENT VARIETIES, 1951 AND 1952.

Year	Mean Percentage Rooting			Mean Score for Vigour (max. 10)		
	Leveller	Keepsake	Careless	Leveller	Keepsake	Careless
1951 ..	48·5	57·5	—	3·5	4·2	—
1952 ..	56·3	61·9	56·0	3·1	6·3	4·8

Note.—1951 means based on 64 plots : 1952 means based on 80 plots.

In neither year was there any significant difference in the overall rooting percentage of different varieties (Table IV). In 1952, however, significant differences were found between the vigour score of different varieties, Leveller making the poorest growth ($L < K$ and C at 0·1% level) and Keepsake the best ($K > C$ at 1·0% level). This is in agreement with the general experience that Leveller is a difficult variety.

(2) *Time of taking and planting the cuttings.*

The results for 1951 (Fig. 1) and 1952 (Table III) are not comparable as different planting times were chosen in each year. In 1951 September and October appeared to be the most favourable months for planting Leveller, and September the most favourable for Keepsake. In 1952 the percentage rooting for August planting did not differ significantly from that of December, but the advantage of getting a cutting established early in the season is shown by the values for vigour.

Samples of cuttings dug up at intervals showed that root formation took place slowly from planting time throughout the dormant period. It would appear that the earlier the planting time the more time the cutting has in which to establish sufficient roots to carry it over the critical period in the following spring. However, planting before the beginning of September may be unwise in general practice owing to the possibility of a dry period occurring soon after planting, which may be fatal.

It appears that " heeling in " for periods of one to two months (Tables I and II, treatments H, J and K) may have a beneficial effect, but this factor needs to be examined over a longer period before any recommendation can be given ; the results certainly do not suggest that this treatment is harmful.

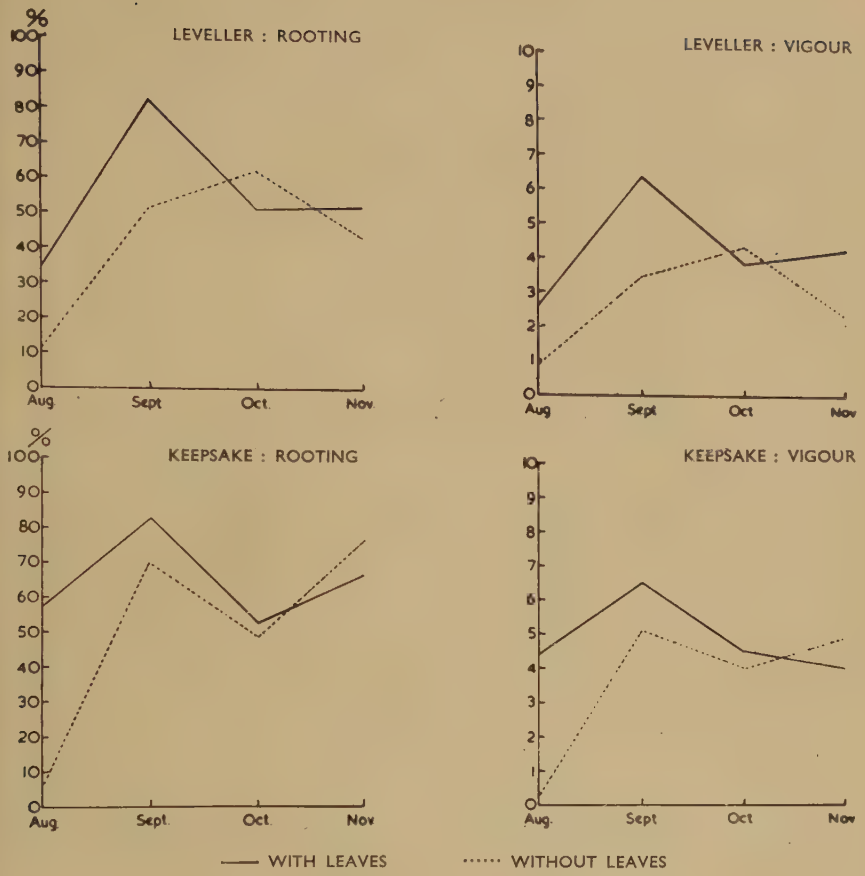


Fig. 1. The effect of leaves and planting time on the percentage take and vigour of gooseberry cuttings, 1951 (vars. Leveller and Keepsake).

Significance levels.

Effect of Leaves :

Rooting : Leveller, August and September at 5%.
Keepsake, August at 0·1%.
Vigour : Leveller, August at 5%, September at 1%.
Keepsake, August at 0·1%.

Time of Planting : (with leaves)

Rooting : Leveller, September > October and November at 5%.
September > August at 0·1%.
Keepsake, September > October at 1%. September > August at 5%.
Vigour : Leveller, September > October at 5%. September > August at 1%.
Keepsake, September > August at 5%. September > November at 1%.

(3) *Leaves.*

In both experiments the rooting of Leveller cuttings taken in August was adversely affected by the removal of leaves (Fig. 1 and Table III). Keepsake was variable in response to leaf removal, and Careless was not affected in the single year in which it was tried : in no instance does the removal of leaves appear to have been advantageous. As would be expected, later in the season the leaves have a diminishing effect until leaf fall.

(4) *Retention of buds on the underground portion of the cutting.*

TABLE V.

THE EFFECT OF BUDS AT DIFFERENT PLANTING TIMES, 1952.

All means based on 24 plots.

	Mean percentage rooting			Mean score for vigour		
	+ buds	— buds		+ buds	— buds	
August ..	72·9	56·3	Sig. at 1% level	7·1	7·1	—
December ..	27·5	61·3	Sig. at 0·1% level	1·9	3·4	Sig. at 0·1% level
	Sig. at 0·1% level	Not sig.		Sig. at 0·1% level	Sig. at 0·1% level	

In August the presence of buds appears to be beneficial for rooting though complications may later arise from suckers. In December, however, the presence of buds has a definitely harmful effect. A series of cuttings planted over a long period would be of interest in determining when these opposing effects are dominant. There was no interaction between the presence or absence of leaves and buds.

(5) *Type of shoot.*

The kind of shoot chosen had no significant influence except on the variety Keepsake, which showed a higher percentage take when using less vigorous shoots with a heel.

(6) *Retention of shoot tip.*

TABLE VI.

SHOOT TIP × TIME. MEAN SCORE FOR VIGOUR, 1952.

All means based on 24 plots.

	+ shoot tip	— shoot tip
August	7·1	4·8
December	4·1	4·7

Retention of the shoot tip had no significant effect on the percentage take of the cuttings of Keepsake and Careless, but increased that of Leveller (Table III). In the August planting the presence of the shoot tip increased the vigour of the cuttings very significantly (vigour score 7·1 as against 4·8—significant at 0·1% level). In the December planting the shoot tip had no effect on vigour.

(7) *Soil conditions.*

TABLE VII.

EFFECT OF SOIL CONDITIONS.

All means based on 120 Plots.

	Soil I.	Soil II.
Percentage rooting ..	58·4	57·7
Vigour/10	5·3	4·2

Cuttings planted on the two soils did not show any difference in percentage rooting but the vigour score was better on Soil I than on the less well drained Soil II (5·3 as against 4·2—significant at 1% level). Abundant moisture generally favours callus formation on hardwood cuttings of some species, but excess callus hinders the uptake of water (3) and unless there is sufficient aeration for root formation above the callus the cutting will fail to grow, beyond producing a few shoot rosettes, though it may stay alive until the following season.

Callus formation on the cuttings.

Samples of all treatments were examined for the amount of callus formation, character and position of roots. The amount of root was well correlated with the recorded score for vigour. The amount of callus varied within each treatment and showed no relation to the number of roots ; in fact, no callus was visible on many well-rooted cuttings. The position of the roots on the cuttings varied within each treatment ; on some cuttings the roots arose solely from just above the basal cut, while in others they were well distributed throughout the portion below ground. Treatment G contained only cuttings having roots of the former type. Roots arising from just above the basal cut did not appear to be dependent on callus formation over the basal cut itself, though it appears that roots arising in this region are developed from callus formed under the bark.

Summary.

(1) The effect of different methods of preparing and treating gooseberry cuttings on percentage rooting and vigour was investigated. The varieties Leveller and Keepsake were used in 1951, and Leveller, Keepsake and Careless in 1952.

(2) Of the three varieties tested cuttings of Leveller proved the most difficult from which to produce a satisfactory bush. The performance of this variety was much improved when leaves were retained on the cutting.

(3) In 1951 cuttings planted in late September gave better results than those planted in August, October or November.

(4) The practice of " heeling in " cuttings for one to two months before planting was found not to be detrimental.

(5) The presence of buds on the portion of the cutting below ground improved the rooting of August planted cuttings, but impaired that of cuttings planted in December.
(6) For cuttings taken in early August the retention of the shoot apex (removed in spring) had a beneficial effect. The shoot apex had no effect when cuttings were taken and planted in December.
(7) The percentage rooting of cuttings on plots with a high water table in winter was not significantly different from that on better drained soil, though the subsequent growth of the cuttings was poorer.
(8) There was no relation between the number of roots produced on a cutting and the amount of callus developed on the basal cut.

Acknowledgments.

Thanks are due to Mr. G. M. Clarke for assistance in the analysis of the results, and to Mr. A. I. Campbell for records of the 1951 experiment.

REFERENCES.

(1) Anon (1951). *Bull. Minist. Agric., Lond.*, No. 4 (Bush Fruits).
(2) Van der Lek, H. A. A. (1934). *Meded. LandbHoogesch., Wageningen*, Deel 38.
(3) Knight, R. C. (1925). *J. Pomol.*, **5**, 248.

THE INFECTION OF APPLE STEMS THROUGH WOUNDS CAUSED BY GEESE.

By E. W. HOBBIS and R. W. MARSH.

As part of a Research Station scheme for further investigations into the behaviour, cropping and vintage qualities of certain cider apple varieties, a number of new plantations, both of bush trees and standards, have been planted in several counties of the Midlands and the South West during recent years. Each trial plantation consists of 120 trees of six or more varieties growing on two vigorous rootstocks, viz. Seedling Crab and Crab " C." The trees were supplied as " maidens " and all were well grown.

At one centre in Gloucestershire where environmental conditions and general management were excellent, trees planted in the winter of 1952-53 made good progress during the 1953 growing season and seemed by autumn to have established themselves well. The varieties were Sweet Coppin, Sweet Alford, Yarlington Mill, Tremlett's Bitter, Medaille d'Or No. 1 and Ashton Brown Jersey. The trees were planted 24 feet apart and the land between was sown to a corn crop which was harvested in August 1953.

In January 1954 an inspection of the plantation showed widespread cankering of the main stems, so severe that some 60 out of 120 trees were rendered useless and many were already dead.

During the spring after planting slight damage occurred here and there due to rabbits, but a smear of Stockholm tar was effective in stopping this and a careful examination showed that the Stockholm tar had had no ill effect on any of the trees.

On examining closely each tree stem in the orchard, however, it was noticed that all the cankered trees, and the cankered trees only, showed a clearly defined pattern of markings on the stems. The marks were in the form of parallel grooves, scored at an angle to the stem on one side, with corresponding grooves or regular puncture marks on the reverse side.

Further enquiry showed that after the corn was harvested geese had been turned into the plantation on October 7th for a period of 15 days, and it seemed possible that damage by the geese might have preceded canker infection. Trees of similar age and size were therefore planted at Long Ashton in a field where geese were feeding : within a few days the trees showed fresh stem wounds identical in form and position with those on the cankered trees.

Isolations from the cankered trees brought from Gloucestershire consistently gave a fungus tentatively identified as a species of *Gloeosporium*. Fragments from pure cultures of this fungus were inserted into small wounds made in the bark of young trees of Egremont Russet growing in a nursery plot at Long Ashton. Within a month each point of inoculation was surrounded by a clearly-defined, sunken, blackened, oval patch of bark approximately $1 \times \frac{1}{2}$ in., closely resembling the lesions found in the Gloucestershire plantation around the injuries caused by geese. Two months after inoculation the diseased bark on the Egremont Russet trees showed fungus fructifications identified as those of *Gloeosporium perennans*.

There is therefore strong evidence that the organism causing the cankers on the goose-damaged trees was *Gloeosporium perennans*. Experiments made

by Mr. A. T. K. Corke on young Cox's Orange Pippin trees at Long Ashton showed that this fungus readily infected wounds made in 2-year-old wood in October and November 1953, and it is probable that the warm humid weather at that time was particularly conducive to natural infection in the field.

Damage bore no relation to variety. All the tree stems injured had a diameter of approximately ½ inch : three-year-old trees planted in the same field at the same time as the " maidens " were untouched. This would seem to show that geese can attack trees of up to ½″ diameter with ease, but that larger diameter trees are not so easily held between the upper and lower mandibles.

Fig. 1 shows a typical example of the markings on the stem and of the clearly defined, sunken, dead area which resulted from subsequent infection.

Figs. 2 and 3 are enlarged to show the appearance of damage by the upper and lower mandibles of a goose's bill on opposite sides of the same stem.

Since geese are sometimes allowed to graze through plantations it seems that the above observations should be recorded and the possible secondary effect of damage by geese noted by growers who may run geese amongst young trees. The protection of each tree by a wire netting collar not less than 2′ 6″ high would effectively prevent this type of injury.

Fig. 1

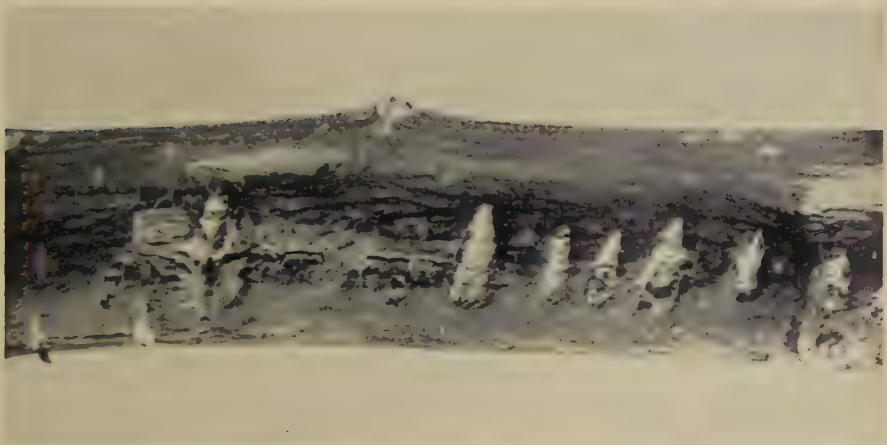


Fig. 2

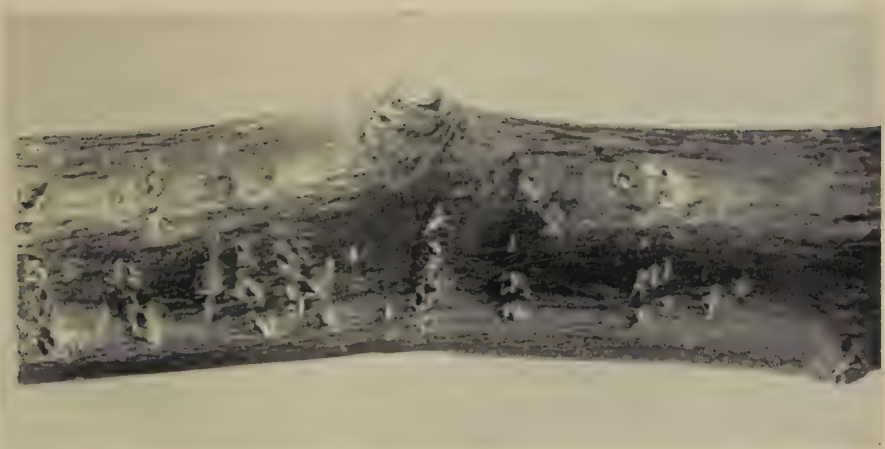


Fig. 3

THE USE OF IRON CHELATES FOR THE CONTROL OF LIME-INDUCED CHLOROSIS IN FRUIT: PROGRESS REPORT I.

By C. BOULD.

Lime-induced chlorosis is a serious problem in fruit orchards on calcareous soils. It was first shown by Bennett (1) and confirmed by Wallace (8) that a temporary control of this type of chlorosis in fruit trees could be obtained by the injection of iron salts into the trunk or branches of affected trees. The treatment has, however, to be repeated every few years for a satisfactory control, and the damage to the trunk resulting from repeated injections may be severe. It has also been shown by Wallace (9) that the grassing-down of affected orchards has a beneficial effect on lime-induced chlorosis; the combination of grassing-down and trunk injection of iron salts is the only practical means of treatment yet known. Application of iron salts to alkaline soils is ineffective because the iron is readily precipitated, while foliage sprays often cause severe scorching and their effect is localised because of the immobilisation of iron at the point of absorption. Demolon and Bastisse (3) suggested the use of pseudo-solutions of ferrisilicate, which they claim to be stable over a wide pH range, for controlling lime-induced chlorosis, but these compounds have not proved effective under conditions at Long Ashton (6).

In 1950 Jacobson (4) showed that the iron chelate of ethylenediamine tetraacetic acid (Fe-EDTA, also known commercially as Versene and Sequestrene) was stable in nutrient solutions containing phosphate and that its addition at the rate of 5 to 10 p.p.m. of iron led to normal growth of tomato and corn plants: no injury occurred to either crop till the concentration of iron was raised to 50 p.p.m. This discovery led Stewart and Leonard (5) to test Fe-EDTA on citrus trees suffering from iron deficiency. They obtained a good response when as little as 10 to 20 g. of complexed iron was applied per tree. (The iron chelates used contained from 6 to 13% of iron). They also showed that 20 g. of chelated iron was more effective than 2,500 g. of iron applied as ferrous sulphate. The Fe-EDTA was applied in solution or absorbed on vermiculite. It should be emphasised, however, that these spectacular results were obtained on trees growing on acid soils (pH 4).

Recently two new chelating agents, that show promise as iron carriers for the treatment of iron chlorosis in plants, have been developed by Chaberek and Bersworth (2). They are N,N′-dihydroxyethylethylenediaminediacetic acid (HEEDDA) and N-hydroxyethylethylenediaminetriacetic acid (HEEDTA). The iron chelates of these two acids and that of a third, diethylenetriaminepentaacetic acid (DTPA) have been shown by Wallace, North, Kofranek and Lunt (7) to be more effective at lower concentrations than Fe-EDTA in correcting lime-induced chlorosis in ornamental trees.

When the field experiments described in this report were started, the only iron chelate obtainable was Fe-EDTA and amounts were limited. The rates of application were based on those of Stewart and Leonard (*loc. cit.*) for citrus growing under acid soil conditions. It has since been shown that these rates are too low for alkaline soils. This should be borne in mind when considering the results of these preliminary experiments.

Experimental.

Four sites were chosen for experiments on red currant, plum and pear, all of which were suffering from severe lime-induced chlorosis. Information on the sites and soils is given in Table I.

TABLE I.

SITES AND SOILS USED.

Site	Location	pH	% $CaCO_3$	Management	Crop
A.	Evesham	7·7	3·4	Arable	Red currant and plum
B.	„	7·8	16·0	„	Pear
C.	„	7·7	7·4	Recent grass	Plum
D.	„	7·8	7·3	Arable	Plum

Site A. *Crop*: Red currant *var.* Laxton's No. 1.

Soil Treatments. Applied 3/3/53.

1. 5 g. of complexed iron per bush as Ferrogrene.*
2. 10 g. of complexed iron per bush as Ferrogrene.
3. Equivalent amount of Na_2-EDTA to treatment 1.
4. „ „ „ „ „ „ 2.
5. 5 g. of ferric iron per bush as NaFe-EDTA
6. 10 g. „ „ „ „ „ „ „
7. 5 g. of ferrous iron „ „ „ „
8. 10 g. „ „ „ „ „ „ „

} prepared from EDTA, ferrous sulphate and sodium hydroxide.

Treatments were applied on a single bush basis and were duplicated. The Ferrogrene was sprinkled round the bushes and watered in. Other treatments were applied in solution. Treatments 3 and 4 were included because Stewart and Leonard (*loc. cit.*) had suggested that Na_2-EDTA was effective in mobilising iron from the soil under acid conditions. Owing to a shortage of Fe-EDTA the iron chelates used in treatments 5 to 8 were prepared in the laboratory from EDTA and ferrous sulphate according to the method of Jacobson (*loc. cit.*). Solutions used in treatments 7 and 8 were not aerated, so that much of the iron was still in the ferrous state when applied to the soil.

Foliage Sprays. Applied 29/4/53.

1. 0·125% Ferrogrene + wetter (sulphonated Lorol).
2. 0·25% „ „ „
3. 0·50% „ „ „
4. 0·125% Sequestrol** + „
5. 0·25% „ „ „
6. 0·50% „ „ „

*Ferrogrene is the trade name for NaFe-EDTA as manufactured by the Bersworth Chemical Co., U.S.A.; it contains 7% Fe.

**Sequestrol iron complex (NA) is the trade name for NaFe-EDTA as supplied by the Geigy Co. Ltd., Manchester; it contains 14% Fe.

Foliage sprays were applied in duplicate to plots each consisting of three bushes.

Crop : Plum *var.* Purple Pershore—old trees.
Soil Treatments. Applied 3/3/53.

1. 10 g. of chelated iron per tree as Ferrogrene.
2. 20 g. ,, ,, ,, ,, ,, ,, ,,
3. 30 g. ,, ,, ,, ,, ,, ,, ,,
4. 10 g. of chelated ferric iron as NaFe-EDTA.
5. 10 g. ,, ,, ferrous ,, ,, ,,
6. Na_2-EDTA at equivalent rate to treatment 1.

Branch Injection 3/3/53.

1. Ferrogrene pills at equivalent iron rate to ferrous sulphate method (Wallace, T., *loc. cit.*).
2. Na_2-EDTA at equivalent rate to Ferrogrene.

Foliage Sprays. Applied 29/4/53.

Foliage sprays were used at the same concentrations as for red currants. All treatments were in duplicate on a tree or branch basis.

Site B. *Crop* : Pear *var.* Conference top-grafted on Fertility on Quince A root-stock ; young trees.

Ferrogrene, ferric-EDTA, ferrous-EDTA and equivalent amounts of Na_2-EDTA were applied to the soil on a tree basis at rates equivalent to 5 and 10 g. of chelated iron per tree on 3/3/53.

Foliage sprays of Ferrogrene and Sequestrol at 0·125% concentration only were applied on 13/5/53.

Site C. *Crop* : Plum *var.* Burbank's Giant Prune ; old trees ; orchard recently grassed-down.

Soil treatments, branch injections and foliage sprays were the same as for plum at site A.

Site D. *Crop* : Plum *var.* Burbank's Giant Prune ; young trees ; orchard clean cultivated.

Soil treatments, foliage sprays and trunk injections were the same as for site A with an additional treatment comparing trunk injections using equivalent amounts of iron as Fe-EDTA and as ferrous sulphate.

Results.

Site A. *Red Currant.*

There was no visual response to soil treatments and no injury to the bushes. Foliage sprays caused slight to medium marginal leaf scorch at 0·5% concentration, a trace at 0·25% and no damage at 0·125%. There was a slight response to foliage sprays but the new growths were chlorotic, indicating that there was little if any translocation of iron within the plant.

Plum.

There was no visual response to soil treatments.

Foliage sprays caused severe leaf scorch at 0·5% concentration, medium

scorch at 0·25% and only a trace of damage at 0·125%. The undamaged area of the leaves became dark green and remained green for the rest of the season showing that iron had been absorbed and metabolised. Injection of solid Ferrogrene improved the colour of the leaves and caused no leaf damage. Injections of equivalent amounts of Na_2-EDTA caused severe chlorosis, marginal leaf scorch and spur die-back. It is thought that the Na_2-EDTA immobilised all the active iron in the injected branches.

Site B. *Pear.*

Soil treatments had no visual effect on the severity of chlorosis.

Foliage sprays at 0·125% concentration caused severe intervenal and marginal scorch indicating that the pear is much less resistant to spray damage than plum and red currant. The undamaged leaf areas became green but new growths developed chlorosis.

Site C. *Plum.*

Soil treatments had no visual effect on chlorosis.

Injections of Na_2-EDTA increased chlorosis and caused marginal scorch and spur die-back.

Foliage sprays caused leaf damage at concentrations greater than 0·125%.

Site D. *Plum.*

Soil treatments had no visual effect on chlorosis.

Injections of Na_2-EDTA resulted in damage and increased chlorosis.

Trunk injections of Fe-EDTA at equivalent iron rates to ferrous sulphate were not so effective as the latter.

Foliage sprays at 0·5% concentration caused severe leaf scorch but undamaged areas were free from chlorosis. Foliage sprays at 0·125% concentration caused no damage and resulted in approximately 50% recovery from chlorosis. The absorption of iron by the leaves occurred in irregular areas, producing a blotchy appearance of contrasting dark green and yellow areas (See Plate, fig. *b*).

Discussion.

It would appear from these preliminary experiments that Fe-EDTA is not effective under alkaline soil conditions when used at rates that are effective under acid soil conditions. When injected into trees at a rate equivalent to the iron in ferrous sulphate it was not so effective as the latter.

Foliage sprays caused damage at concentrations in excess of 0·1%. Of the crops tested susceptibility to spray damage was in the order pear > plum > red currant. The response to foliage sprays of 0·1% concentration was only partial and probably two or more sprays at intervals of 2–3 weeks would be necessary to produce a complete seasonal control of lime-induced chlorosis.

Field experiments are in progress to test Fe-EDTA at increased rates of application together with trials of some of the other iron chelates mentioned in the introduction. Studies using the soil perfusion technique are also being made of the stability and persistence of different concentrations of iron chelates under varying soil conditions.

(*a*) Plum : var. Burbank's Giant Prune suffering from severe lime-induced chlorosis.

(*b*) Plum : A fortnight after spraying with a 0·1% solution of Fe-EDTA.

Acknowledgments.

I wish to express my thanks to Mr. A. W. E. Roberts of the N.A.A.S. for suggesting the sites and for his general interest in the experiments, to Messrs. Andrews, Barnard and Stokes for permission to use their orchards, and to the Bersworth Chemical Co. of the U.S.A. and the Geigy Co. Ltd., Manchester for supplying the iron chelates.

REFERENCES.

(1) Bennett, J. P. (1931). *Univ. Calif. Exp. Sta. Circ.*, No. 321.
(2) Chaberek, S. and Bersworth, F. C. (1953). *Science*, **118,** 280.
(3) Demolon, A. and Bastisse, E. M. (1944). *Ann. Agron.*, **14**, 265.
(4) Jacobson, L. (1950). *Plant Physiol.*, **26**, 411.
(5) Stewart, I. and Leonard, C. D. (1952). *Citrus Mag.*, June 1952.
(6) Tolhurst, J. and Bould, C. (1950). *Ann. Rep. Long Ashton Res. Sta.*, 1949, 40.
(7) Wallace, A., North, C. P., Kofranek, A. M. and Lunt, O. R. (1953). *Calif. Agric.*, **7** (10) 13.
(8) Wallace, T. (1929). *J. Pomol.*, **7**, 251.
(9) —— (1935). *Ibid.*, **13,** 54.

THE EFFECT OF CHEMICAL STRUCTURE ON BIOLOGICAL ACTIVITY: THE SIGNIFICANCE OF CHLORINE IN CERTAIN INSECTICIDES, FUNGICIDES AND PLANT GROWTH-REGULATORS.

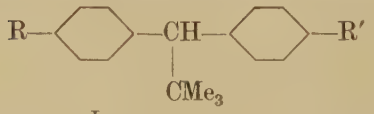
By D. WOODCOCK.

The outstanding insecticidal, fungicidal or plant growth-regulating activity of synthetic organic compounds now used in agriculture and horticulture has aroused interest in the effect of both major and minor structural alterations in the molecules involved. In recent years systematic research, at Long Ashton and elsewhere, has been devoted to a better understanding of the effect of chemical structure on biological activity. A striking feature of the Long Ashton work on insecticides, fungicides and plant growth-regulators, which is brought together in this paper, has been the varying significance of the number and position of chlorine atoms in the molecules that have been prepared and examined. Further examples of the biological equivalence of the chlorine atom and the methyl group have also been provided, though exceptions have been noted.

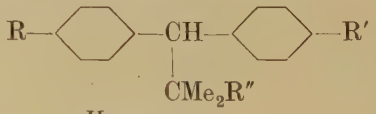
Contact Insecticides.

In a study of an early German insecticide prepared by the side-chain chlorination of *p*-chloroethyl benzene, some of the compounds likely to be present were prepared pure for bioassay (1). It was found that the relative potency of the compounds as contact insecticides against *Calandra granaria* increased with increasing chlorine content of the side-chain, though the completely chlorinated product *p*-$Cl{\cdot}C_6H_4{\cdot}CCl_2{\cdot}CCl_3$ was virtually non-toxic.

Work on the insecticidal action of DDT has been on a more extensive scale. Anomalies arising from the early theories of Läuger, Martin and Müller (2) and of Martin and Wain (3) led to a consideration of the possibility that the toxicity of DDT might be due to its structural resemblance to some essential insect metabolite (4). The first synthesis of a series of isosteric analogues of DDT was reported (5) in 1950 and later an unambiguous method of synthesis was developed (6, 7). In this work advantage has been taken of the close spatial similarity of the chlorine atom (radius 1·8 Å) and the hydroxy (radius 1·7 Å) and methyl (radius 2·0 Å) groups, the close agreement of these sizes having been previously shown by Pauling and Pressman (8) to be well within the limits required for isosteric activity in serological reactions.



I

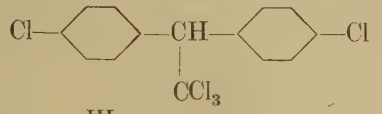


II

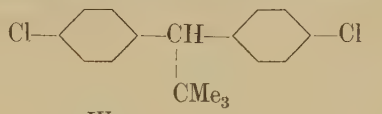
Tested as contact insecticides against the grain weevil, *Calandra granaria*, the isosteres (I; R=R′=Cl; R=R′=Me; R=Cl, R′=Me and II; R=R′=Cl, R″=OH; R=R′=Me, R″=OH; R=R′=R″=Cl; R=R′=Me, R″=Cl) showed little or no activity, and a sample of the dimethoxy isostere (I; R=R′=OMe) obtained from Brown and Rogers (9) was also inactive.

The American workers, on the other hand, claim for this compound insecticidal activity of the same order as that of the DDT analogue "methoxychlor" against German cockroaches, milkweed bugs and various larvae. The production of characteristic DDT tremors and the observation of decreased effectiveness against DDT-resistant flies seem to substantiate the view that it is a DDT-type insecticide. It must be pointed out, however, that the dosages employed (400-2,000 mg./kg.) in the work by the American workers are never used in bioassays at Long Ashton—compounds being considered non-insecticidal when required at dosage-levels of this order.

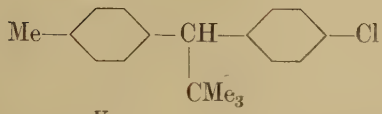
Using the cotton-stainer, *Dysdercus fasciatus*, which is akin to the milkweed bug, it has been shown (10) that some of the isosteres do show slight activity as contact insecticides, indicating a higher level of susceptibility in this insect than in the grain weevil. Thus in the series shown below, where there is a progressive substitution of methyl groups for chlorine atoms, only DDT (III) has any activity against *C. granaria* whereas with *D. fasciatus* the isosteres



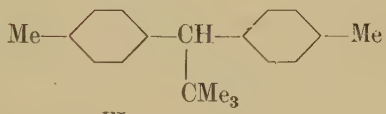
III



IV



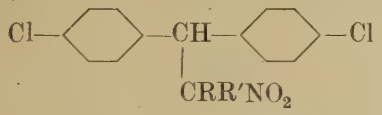
V



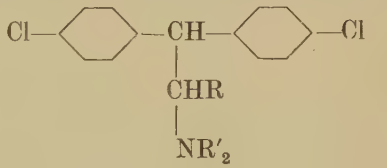
VI

IV and V show slight activity and only VI is completely non-toxic.

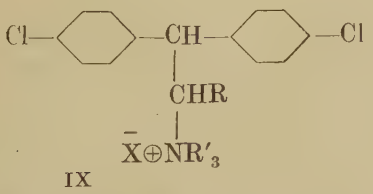
The suggestion that the high insecticidal activity of DDT might be associated in some way with the presence of strongly electropositive groups in the aliphatic portion of the molecule was advanced by us in 1951 (11) and a number of di-*p*-chlorophenylalkanes (VII-IX) were prepared and examined (12).



VII



VIII



IX

One of the most significant results in this work was obtained by the introduction of successive chlorine atoms into the compound (VII ; R=R′=H) which was inactive against both the grain-weevil and the cotton-stainer. The compounds (VII ; R=H, R′=Cl, and R=R′=Cl) were still both inactive against the grain weevil, despite the close spatial and electrical similarity between the dichloro- compound and DDT. The mono-chloro compound

(VII ; R=H, R′=Cl) has since been shown to be considerably toxic to the cotton stainer. A complete review of the results obtained with the isosteres and analogous compounds using both insect species is being prepared (10) with special reference to the " trihedralisation " theory of DDT activity (13). This theory suggests that the toxicity of DDT can be satisfactorily explained in terms of a trihedralised *pp′*-di-chlorophenylmethyl moiety, the prime function of the trichloromethyl group being to cause the two *p*-chlorophenyl residues to take up positions of maximum clearance, i.e. positions corresponding to the sides of a trihedral angle.

Protective and Systemic Fungicides.

Early work of Crowdy (14) had shown that some naphthyloxy alkyl carboxylic acids were more effective than phenoxy acids in reducing the growth *in vitro* of the fungus *Nectria galligena*, and that introduction of nuclear chlorine appeared to enhance fungitoxicity. Potential systemic fungicidal agents should not show growth-promoting properties, and it was therefore decided to examine for systemic fungitoxicity all mono-, di- and trichloro-2-naphthyloxy-n-aliphatic carboxylic acids originally prepared as potential parthenocarpic agents but found to be inactive as such. If lower members of a series showed promise, higher members were also prepared. The compounds were tested as systemic fungicides against the chocolate spot of broad bean caused by *Botrytis fabae*, and as fungicides *in vitro* by their effect on the germination of spores of *Sclerotinia laxa* and on the growth of *B. fabae* mycelium (15).

Fungicide tests with 1:3-dichloro-2-naphthol derivatives suggested that there was some increase in toxicity to the spores of *S. laxa* with increasing length of side-chain, and this series was accordingly prepared up to ϵ-(1:3-dichloro-2-naphthyloxy)-n-caproic acid. The systemic fungicide tests showed no difference in the activity of compounds associated with different side chains though there was a slight but significant effect associated with different chlorine substitutions in the nucleus. Of the compounds tested, the 3:4-dichloro-2-naphthol derivatives were the most effective as systemics and the least toxic to the pathogen *in vitro*. The fact that the 3:4-dichloro-2-naphthyloxy compounds were also found to be least damaging to the host plant and most effective in disease reduction suggested that phytotoxicity and disease reduction may be related. 3:4-Dichloro-2-naphthol itself did indeed give the tallest plants and the smallest fungal lesions. It was also found that the naphthols were generally as active systemically as the corresponding naphthyloxy acids, a result which viewed in the light of the mechanism of disease reduction may well be significant. A similar observation does not appear to have been recorded by workers in the phenoxy series.

Fungitoxicity-phytotoxicity relationships have also been examined using 2:3-dichloronaphthaquinone and some related compounds (16, 17). These were tested in aqueous acetone solution against *S. laxa*, *B. fabae*, *Cladosporium fulvum* and *Venturia inaequalis*. The corresponding hydroquinone showed the same order of fungicidal activity as the parent quinone and was just as phytotoxic as the quinone to plum fruitlets and to tomato and broad bean foliage. Whilst the dibenzoyl ester and dimethyl ether of the hydroquinone proved virtually inactive, the diacetate, dipropionyl and dibutyryl esters were

found to be as active as 2:3-dichloro-1:4-naphthaquinone and also much less phytotoxic. Moreover the rates of hydrolysis of these esters have been determined and there appears to be some relationship between ease of hydrolysis and fungicidal activity. It is suggested that these substances, whilst not inherently active, are hydrolysed to 2:3-dichloro-1:4-naphthahydroquinone in the presence of a fungal esterase, the liberation of toxic material occurring only in the immediate vicinity of the spore. This view is strengthened by experiments using *V. inaequalis* against which the diacetyl ester was relatively ineffective. Addition of an enzyme preparation exhibiting high acetyl-esterase activity markedly increased the susceptibility of the fungus.

The significance of the two vicinal chlorine atoms in the 1:4-naphthaquinone nucleus for high fungicidal activity is emphasised by the inactivity of the isosteric compounds 2:3-dimethyl- and 2-chloro-3-hydroxy-1:4-naphthaquinone and the reduced activity of the isomeric ortho-quinone, 3:4-dichloro-1:2-naphthaquinone.

Plant growth-regulators.

The ability of β-naphthyloxyacetic acid to induce parthenocarpic development of unpollinated tomato ovaries has formed the basis of the main theme for research on plant growth-regulators. The effect of the number and position of substituent halogen atoms in many substituted phenoxyacetic acids has been investigated by various workers, notably Zimmerman and Hitchcock (18), Synerholm and Zimmerman (19) and Leaper and Bishop (20). Before an investigation of substituted β-naphthyloxyacetic acids could be made, a survey of the synthetic methods available for the preparation of chloro-2-naphthols was necessary since these were commercially unavailable and poorly described in the literature. This has resulted in new syntheses for 5-, 7- and 8-chloro-2-naphthols, the former having been prepared probably for the first time (21). A mode of formation of 1:x-dichloro-2-naphthols has also been developed and the previously erroneously recorded 1:6-dichloro-2-naphthol has been unambiguously prepared and fully described (22). During the course of this work an unusual and hitherto unknown property of hydrobromic acid was discovered, namely its ability to substitute bromine for nuclear chlorine during normal demethylation procedure.

From the nuclear chlorine-substituted naphthols, various series of α- and ω-substituted aliphatic carboxylic acids were prepared and their physiological activity measured by their ability to induce parthenocarpic development of unpollinated tomato ovaries. This test was used because of the inactivity of the naphthyloxy compounds in the *Avena* curvature and coleoptile cylinder tests. The results of this survey of the relationship between the molecular structure of the 2-naphthyloxy compounds and their biological activity as growth regulating substances are practically complete. It has been shown that only in the 3-position of the naphthalene nucleus does a substituent chlorine atom not affect the activity of the parent 2-naphthyloxyacetic acid ; all the other mono-, di- and tri-substituents that have been examined cause a reduction in activity and sometimes destroy it completely (23). These results are in complete contrast to the recent work of Sell and co-workers (24) who found that mono-substitution of chlorine in any position in the phenyl nucleus of indole-3-acetic acid increased activity ten-fold in the tomato parthenocarpic

fruit test. Numerous 2-naphthyloxyaliphatic carboxylic acids prepared by us also showed markedly reduced activity, whether substituted in the α- or ω-position of the side-chain.

The influence of side-chain length on the activity of ω-(2-naphthyloxy)-n-alkyl carboxylic acids (25) for the induction of parthenocarpy in tomatoes has been examined in two homologous series. In the ω-(2-naphthyloxy) series it was found (26) that only those acids having an even number of carbon atoms in the side-chain were active as growth regulators, a result that can be explained on the β-oxidation hypothesis of Synerholm and Zimmerman (27). The acids with 8 and 10 carbon atoms in the side-chain were much less active than would be expected on the basis of complete β-oxidation. It is suggested that these acids undergo partial ω-oxidation such as has been found to occur in animal metabolism with fatty acids having 8-11 carbon atoms. In the 3-chloro-2-naphthyloxy series, whilst the introduction of the chlorine atom in position 3 of the naphthalene nucleus did not affect the activity of the first member, the activity of the higher homologues was completely destroyed, presumably because the β-oxidation process had been blocked.

Acknowledgments.

Thanks are due to Mr. A. Stringer, Dr. L. C. Luckwill and Dr. R. J. W. Byrde for their collaboration.

REFERENCES.

(1) Woodcock, D. (1949). Insecticidal activity and chemical constitution. Part I. Chlorinated *p*-chloroethylbenzenes. *J. chem. Soc.*, 203–207.

(2) Läuger, P., Martin, H. and Müller, P. (1944). Constitution and toxic action of natural and modern synthetic insecticides. *Helv. chim. Acta*, **27**, 892.

(3) Martin, H. and Wain, R. L. (1944). Insecticidal action of DDT. *Nature*, **154**, 512.

(4) Skerrett, E. J., Stringer, A. and Woodcock, D. (1950). Insecticidal action of DDT. *Nature*, **165**, 853.

(5) Skerrett, E. J. and Woodcock, D. (1950). Insecticidal activity and chemical constitution. Part II. Synthesis of some analogues of DDT. *J. chem. Soc.*, 2718–2724.

(6) Skerrett, E. J. and Woodcock, D. (1952). Insecticidal activity and chemical constitution. Part III. A new synthetic route to methyl analogues of DDT. *J. chem. Soc.*, 2804–2806.

(7) Skerrett, E. J. and Woodcock, D. (1952). Insecticidal activity and chemical constitution. Part IV. Synthesis of 2:2-di-*p*-chlorophenyl-3-methylbutane. *J. chem. Soc.*, 2806–2810.

(8) Pauling, L. and Pressman, D. (1945). Serological properties of simple substances IX. Hapten inhibition of precipitation of antisera homologous to the *o*-, *m*-, and *p*-azophenylarsonic acid groups. *J. Amer. chem. Soc.*, **67**, 1003–1012.

(9) Brown, H. D. and Rogers, E. F. (1950). The insecticidal activity of 1:1-dianisylneopentane. *J. Amer. chem. Soc.*, **72**, 1864.

(10) Skerrett, E. J., Stringer, A. and Woodcock, D. (unpub.).

(11) Skerrett, E. J., Stringer, A. and Woodcock, D. (1951). The insecticidal action of DDT. *Biochem. J.*, **49**, xxviii.

(12) Skerrett, E. J. and Woodcock, D. (1952). Insecticidal activity and chemical constitution. Part V. Synthesis of some di-*p*-chlorophenylalkanes. *J. chem. Soc.*, 3308–3312.

(13) Rogers, E. F., Brown, H. D., Rasmussen, I. M. and Heal, R. E. (1953). The structure and toxicity of DDT insecticides. *J. Amer. chem. Soc.*, **75**, 2991–2999.

(14) Crowdy, S. H. (1948). A progress report on the effect of certain organic acids on the growth of *Nectria galligena*. *Ann. Rep. Long Ashton Res. Sta.*, 1947, 158.

(15) Byrde, R. J. W., Crowdy, S. H. and Woodcock, D. (1953). Studies on systemic fungicides : III. The activity of certain chlorine-substituted β-naphthols and naphthyloxy-n-aliphatic carboxylic acids as systemic fungicides. *Ann. appl. Biol.*, **40**, 152–165.

(16) Byrde, R. J. W. and Woodcock, D. (1952). Fungicides and phytotoxicity. *Nature*, **169**, 503.

(17) Byrde, R. J. W. and Woodcock, D. (1953). Fungicidal activity and chemical constitution : II. Compounds related to 2:3-dichloro-1:4-naphthaquinone. *Ann. appl. Biol.*, **40**, 675–687.

(18) Zimmerman, P. W. and Hitchcock, A. E. (1942). Substituted phenoxy and benzoic acid growth substances and the relation of structure to physiological activity. *Contr. Boyce Thompson Inst.*, **12,** 321–342.

(19) Synerholm, M. E. and Zimmerman, P. W. (1945). The preparation of some substituted phenoxy alkyl carboxylic acids and their properties as growth substances. *Contr. Boyce Thompson Inst.*, **14,** 91–104.

(20) Leaper, J. M. F. and Bishop, J. R. (1951). Relation of halogen position to physiological properties in the mono-, di- and trichlorophenoxy-acetic acids. *Bot. Gaz.*, **112,** 250–258.

(21) James, (Miss) P. M. and Woodcock, D. (1951). Synthesis of plant-growth regulators. Part I. Substituted β-naphthyloxyacetic acids. *J. chem. Soc.*, 3418–3421.

(22) James, (Miss) P. M. and Woodcock, D. (1953). Synthesis of plant-growth regulators: Part II. Dichloro-β-naphthyloxyacetic acids. *J. chem. Soc.*, 2089–2093.

(23) Luckwill, L. C. and Woodcock, D. (unpub.).

(24) Sell, H. M., Wittwer, S. H., Rebstock, T. L. and Redeman, C. T. (1953). Comparative stimulation of parthenocarpy in the tomato by various indole compounds. *Plant Physiol.*, **28,** 481.

(25) Pope, (Mrs.) P. M. and Woodcock, D. (1954). Synthesis of plant-growth regulators. Part III. Some ω-(2-naphthyloxy)-n-alkylcarboxylic acids. *J. chem. Soc.*, 1721.

(26) Luckwill, L. C. and Woodcock, D. (1954). Plant-growth regulators. Part I. The influence of side-chain length on the activity of ω-(2-naphthyloxy)-n-alkylcarboxylic acids for the induction of parthenocarpy in tomatoes. (in press).

(27) Synerholm, M. E. and Zimmerman, P. W. (1947). Preparation of a series of ω-(2:4-dichlorophenoxy)-aliphatic acids and some related compounds with a consideration of their biochemical rôle as plant-growth regulators. *Contr. Boyce Thompson Inst.*, **14,** 369.

APPLICATIONS OF THE RADIOACTIVE TRACER TECHNIQUE TO PROBLEMS IN PLANT NUTRITION AND CROP PROTECTION.

SUMMARY OF EXPERIMENTS DURING THE PERIOD 1948-1953.

By W. D. E. THOMAS.

In a previous publication (1) the principles underlying the use of the Geiger Muller counter method for the quantitative measurement of radioactivity were given. The present article summarises the experimental work involving radioactive tracers carried out at Long Ashton during the last five years.

Problems concerning plant nutrition and systemic insecticides have been investigated in collaborative work. Most of the work has involved the radioactive isotope of phosphorus, ^{32}P, but preliminary tests have been carried out with ^{59}Fe, the 47-day isotope of iron. In this article only the principal features that have emerged from the experiments will be discussed, fuller information being given in the published papers listed in the references.

Radioactive assay.

In the earlier work radioassay was made by oxidising all phosphates to the orthophosphate state, precipitating as the magnesium ammonium salt and igniting it to the pyrophosphate. The powder was quantitatively transferred to special shallow counting trays and assayed in a lead castle using a GM2 or GM4 counting tube. With the development of the M6 tube by Veall, permitting a direct count on the plant digest, the end-on window counting of precipitates was abandoned and the more convenient M6 liquid counter adopted for all subsequent work, including the preliminary ^{59}Fe assays. During counting, the tube was shielded from extraneous radiation and light in a suitably designed lead castle. The standard stock solution was counted after every two or three plant solutions, and in this way radioactive decay of the tracer and also small variations in counter efficiency were allowed for.

The scaler used was a model 22 GM counter with scales of 8, 16 and 32 supplied by Panax Equipment Ltd., and modified by them to involve a quench circuit. Counting rates below 2,500 per min. were preferred, since for these the "dead time" correction never exceeded 1% of the counting rate. Where practicable, counting was carried out to give a statistical precision of the order of 1%, but with solutions having very low activities a lower degree of precision of counting had of necessity to be accepted.

The manner in which the various results were computed is described in the relevant papers listed in the references.

Safety Precautions.

The safety precautions adopted were designed to prevent the inhaling and ingestion of any radioactive material, and to minimise the effect of direct radiation from the disintegrating tracers on the personnel carrying out the experiments. The effectiveness of the precautions adopted was tested in two

ways—by the National Physical Laboratory film badge service, and by 3-monthly blood count checks at the Bristol Royal Infirmary arranged with the co-operation of Professor Perry. In no case was there any indication of a harmful dose being received by any member of the team.

A. PLANT NUTRITION.

1. Chemical form of the radioactive material (with D. J. D. Nicholas)

Nutrition problems were the first to be studied and, at the end of the first season's work (1948), a chance experiment led to further work which proved that the chemical form of the ^{32}P supplied was not homogeneous. It is an assumption in quantitative tracer work of this kind that the molecules containing the stable and radioactive isotopes are similar, since only then can it be assumed that the living tissues will not differentiate between them. It transpired that the radioactive material used had been prepared by direct irradiation of sodium orthophosphate in the Pile, and this resulted in about half of the ^{32}P atoms produced being present in a chemical form other than orthophosphate. A note was published on those findings (2) and afterwards all requests for radioactive phosphate were accompanied by the stipulation that the ^{32}P must be present entirely as orthophosphate.

2. Radiation effects from radioactive tracers

(with C. Bould and D. J. D. Nicholas)

The use of radioactive tracers in the investigation of a nutrition problem can be justified only if it is assumed that no serious injury is caused to the plants by the radiation from the disintegrating tracer. Whilst any radiation inevitably produces some cytological changes, it is necessary to establish that such changes do not affect the metabolism of the plant sufficiently to invalidate the main treatment differences under investigation, i.e. the tracer itself must not induce changes in dry weight, total phosphate, fertiliser phosphate and soil phosphate contents of the plant tops and roots. Two conflicting views were held as to the extent of tracer effects. The first was that plants treated with radioactive dosages many times larger than is usual in nutrition experiments suffered no visible ill effects, and the second, possibly arising from different experimental conditions, was that damage produced by radiation was a serious factor—thus in one case it had been shown that the total phosphate content of tomato roots growing in water culture containing 50 $\mu c.$ ^{32}P per litre was reduced to 40% of that present in controls. In view of these conflicting views, it was necessary to determine, under the experimental conditions to be used at Long Ashton, the magnitude of any effects attributable to tracer.

Four experiments were carried out over two years. The procedure in each experiment was to grow tomato plants or barley in soil contained in 6 in. pots, to which the phosphate fertiliser was supplied in solution as one dose of labelled sodium phosphate. Two carrier levels of phosphate were used, and each of these was associated with one of six ^{32}P levels varying from 0 to 500 $\mu c.$ ^{32}P per pot; the other nutrients required for normal growth were added at the same time as the phosphate solution. The plants were harvested after periods of up to nine weeks following application, divided into tops and roots, dried, weighed, digested with acid, analysed for total phosphate etc.

and the fertiliser and soil phosphate contents of each digest determined by radioassay.

The investigation showed that despite the use of ^{32}P concentrations far greater than those normally used in tracer work, and of higher specific activities (up to 29,000 μc. ^{32}P per g. ^{31}P) than those adopted by previous workers, radiation effects as defined above occurred infrequently. Such effects as were observed were small, never exceeding 15% of the control values, and their incidence was not related to the tracer level—they might for instance occur at a low level but not at a higher one.

These findings have been published (3, 4, 5); it has been considered that the overall effects of radiation, under the experimental conditions at Long Ashton, are too slight to invalidate the use of the tracer technique. For experiments requiring a high degree of precision it is suggested that more than one ^{32}P level should be employed at each carrier level so that at the conclusion of the experiment the significance of any tracer effect can be determined.

3. Heavy metal effects on plants grown in soil (with D. J. D. Nicholas)

Attention was then given to a specific problem—the effects of heavy metals on plants grown in soil culture. The development in plants of symptoms of iron chlorosis following heavy phosphate applications is well known; it was therefore of interest to determine the changes in phosphate level occurring in plants in which the symptoms of iron chlorosis had been induced by a heavy metal. By the use of labelled phosphate it was possible to measure the amounts of phosphate taken up by the plants from the soil and from the added fertiliser.

(i) *Effect of cobalt on tomato.*

In the first experiment (1951), 228 six in. pots were used in a factorial experiment involving the addition of three levels of cobalt (0, 1 and 4 milli-equivalents per pot) to soil derived from New Red Sandstone taken from grass plots receiving NK (omit P) treatments. The test crop was tomato, one seedling per pot. A week after transplanting the seedlings in the test soil a supplement including N, K and Mg was given to each pot, followed by the labelled phosphate at rates equivalent to 500 lb. and 1,000 lb. superphosphate/acre. In an extra replicate the effect of adding Mo as sodium molybdate to the Co treated plants was examined. Each phosphate carrier level was labelled with 0, 2 and 4 μc ^{32}P as orthophosphate per pot. After 3 and 6 weeks the roots and tops were harvested separately, dried, weighed and acid digested. Total P, iron and cobalt were determined colorimetrically. Fertiliser P was determined by radioassay and soil P obtained by difference from total P.

Visual symptoms.

Iron chlorosis symptoms soon developed at the highest Co level; the plants remained stunted and necrotic areas developed on the stem and petioles. The injurious effects of cobalt were less marked at the higher P fertiliser level; molybdenum was without effect in alleviating the chlorotic symptoms.

Chemical and radio assays.

It was found at both sampling dates that the amount of dry matter, total

P and fertiliser P in roots and tops was significantly depressed by increases in the Co level, and increased by the higher application of P fertiliser. The concentrations of total and fertiliser P in the plant material was similarly affected except that at the second sampling the concentration of total P in the roots was unaffected by an increase in the Co level.

At the first sampling the content of soil P in the whole plant (tops + roots) was progressively decreased by increases in the Co level, but at the second sampling only the highest Co level proved depressant. The concentration of soil P in the dried plant material was not affected by the Co level at the first sampling but at the later one the concentration increased with increasing Co level. At both samplings the concentration of soil P was significantly greater in the plants receiving the lower application of P fertiliser (6).

(ii) *Effect of nickel on tomato.*

In the following year a parallel experiment was carried out in which the heavy metal was nickel (7), applied at three levels, 0, 15 and 30 milliequivalents per pot. The design, experimental procedures and assays were similar to those used with cobalt.

Visual symptoms.

Mild symptoms of iron chlorosis developed, becoming more severe with age and leading to severe necrosis of leaves and petioles. Following the collapse of the cortical tissues of the stems the plants acquired a bent-over habit; they recovered later and subsequent growth was upright. In contrast to the behaviour with cobalt there was no visible alleviation of the severity of the Ni induced symptoms at the higher P fertiliser level.

Chemical and radio assays.

As with cobalt an increase in the level of Ni caused significant decreases in the amounts of dry matter, total and fertiliser P in plant roots and tops; the concentration of total P in the dried roots was, however, not affected by increasing Ni at the first sampling and was *increased* at the second sampling.

Whilst Ni reduced the total amount of soil P present in the whole plants at both sampling dates, there was only a slight reduction (significant at 5% level) in the concentration of soil P in the dry matter at the first sampling and none at the later one; at this sampling the concentration of soil P was greater in plants receiving the lower P fertiliser application.

The introduction of phosphate in the test seedlings made it impossible to determine separately the subsequent concentrations of soil P in the roots and tops. If, however, in conjunction with the failure of both Co and Ni to depress the concentration of total P in the roots, one considers their slight effect on the concentration of soil P (as opposed to their marked depression of total P) in the whole plants, it appears likely that the metals have caused an accumulation of soil P within the roots. As this effect was observed at both levels of P fertiliser it appears to arise directly from the metal rather than by interaction with the fertiliser.

This possible accumulation of soil P in the roots is of interest, since the precipitation of ferric phosphate in plant roots has been suggested as one way in which the flow of iron is retarded in the aerial parts of the plant.

In neither experiment was there any correlation between the appearance of iron chlorosis symptoms and the iron concentration in the plants.

4. Effect of cover crops on fruit tree nutrition

(with C. Bould and J. A. H. Tolhurst)

Other work was concerned with the effect of grass cover crops and clean cultivation on apple tree growth. Bould *et al.* (8) had shown that after grassing down treatment the P and K concentrations in the leaves of apple trees were increased, and the N concentration depressed, but since the trees were large it was not known whether the grass treatment had increased the total amount of phosphate in the trees. To investigate this question, apple stocks growing in 10 in. pots were treated with radioactive phosphate fertiliser applied at the same time as the other nutrients. Two experiments were carried out, in 1950 and 1952; in each experiment half the pots were kept under clean cultivation, and rye grass seeds were sown in the others. ^{32}P was applied to all pots as orthophosphate, with sodium orthophosphate as carrier, to simulate a dressing of 4 cwt. superphosphate per acre.

The results were studied in relation to the effects of grass and of added nitrogen (9).

B. INSECTICIDE STUDIES.

Systemic insecticides provide a classic example of the use of radioactive tracer technique to obtain information which would otherwise be extremely difficult, if not impossible, to obtain. Systemic insecticides can be absorbed by plants through the leaves or roots and subsequently transported within the plant so that parts remote from the site of application become toxic to insects. Such insecticides clearly possess many advantages but since they are generally toxic to mammals and, once absorbed, are not leachable by rain, the factors that promote or retard their absorption, translocation and breakdown into non-toxic compounds require careful investigation.

Most of the Long Ashton insecticide work involving radioactive material has been carried out with schradan, octamethylpyrophosphoramide, in which one of the phosphorus atoms in the molecule is replaced by a ^{32}P atom. During the late summer of 1953 some work was also undertaken with one of the constituents of the systemic insecticide Systox. The insecticide work can be conveniently discussed under two headings.

1. Physical factors determining the evaporation, absorption, translocation and breakdown of schradan following foliar application.

During the period 1950-3 an investigation has been carried out, in collaboration with S. H. Bennett, to determine the role of some physical factors in the processes which follow foliar application of schradan—its evaporation from, and absorption into the leaves, and its subsequent translocation and breakdown within the plant at different times of the year. The species of plants studied were apple, broad and runner bean, chrysanthemum and *Coleus*.

Preliminary data were presented in 1951 (10, 11); the completed work is now being published in 3 parts (14, 15, 16).

Part I is a description of the experimental procedures and techniques used throughout this work. Part II deals with the two processes, evaporation

and absorption, following the application of schradan to leaf surfaces. Part III provides information on translocation and ultimate breakdown. Systemic efficiency is clearly determined by the direction, speed and extent of movement of the schradan within the plant, and also by the rate at which breakdown occurs. The paper describes the effects observed in different plant species.

2. The contamination of nectar and honey by schradan.

An investigation in collaboration with G. D. Glynne Jones of Seale Hayne Agricultural College was carried out to assess the risk of contamination of nectar and honey by schradan following translocation to the nectaries from the sprayed leaves, even if no flowers were open at the time of spraying. Since schradan is relatively non-toxic to the honey bee and nectar represents secreted phloem sap, it was evident that nectar contamination was at least possible.

Leaves of borage and mustard—two plants that secrete nectar freely—were sprayed with labelled schradan. All flowers which opened during spraying and on the following few days were removed and nectar was collected during the following 3–4 weeks.

It was shown that schradan did appear in an unchanged form in the nectar; that the concentration of insecticide was highest (about 5 p.p.m.) during the first few days of sampling, and fell to low values by the end of the month. Tests on the stability of schradan in contact with the honey stomach of the worker bee and in prolonged storage in honey confirmed that little breakdown would occur under these conditions. If nectar becomes contaminated with schradan it is therefore possible that the insecticide will be present in the honey.

At present in Britain no crops that are important sources of honey are sprayed with schradan immediately before flowering. The investigation, however, has drawn attention to the need to consider carefully the crops for which schradan is to be recommended (12, 13).

Similar work was begun in the late summer of 1953, using the ^{32}P labelled active ingredient of Systox, 0, 0-diethyl S-ethylmercaptoethyl thiophosphate. This work is in progress and will be reported later.

REFERENCES.

(1) Thomas, W. D. E. (1949). Radioactive isotopes—an introduction to their properties and applications to plant nutritional studies. *Ann. Rep. Long Ashton Res. Sta.*, 1948, 114–123.

(2) Thomas, W. D. E. and Nicholas, D. J. D. (1949). Radioactive phosphorus in biochemical research. *Nature*, **163,** 719.

(3) Bould, C., Nicholas, D. J. D. and Thomas, W. D. E. (1951). Radiation effects in plant nutrition experiments with Phosphorus-32. *Nature*, **167,** 140.

(4) ——, —— and —— (1952). Radiation effects with phosphorus-32 in barley and tomato plants grown in soil. *Int. Soc. Soil Sci., Dublin*, 1952, **2,** 92.

(5) ——, —— and —— (1953). Radiation effects with radioactive phosphorus in barley and tomato grown in soil. *Plant and Soil*, **5,** 36.

(6) Nicholas, D. J. D. and Thomas, W. D. E. (1953). Some effects of heavy metals on plants grown in soil culture. Part I. The effect of cobalt on fertiliser and soil phosphate uptakes and the iron and cobalt status of tomato. *Plant and Soil*, **5,** 67.

(7) —— and—— (1954). Some effects of heavy metals on plants grown in soil culture: Part II. The effect of nickel on fertiliser and soil phosphate uptakes and iron and nickel status of tomato. *Plant and Soil*, **5,** 182.

(8) Bould, C., Tolhurst, J. A. H. and Jarrett, R M. (1953). Cover crops in relation to soil fertility and fruit tree nutrition: an experiment with bush cider trees. Final report. *Ann. Rep. Long Ashton Res. Sta.*, 1952, 63–71.

(9) Bould, C., Thomas, W. D. E. and Tolhurst, J. A. H. (1954). Cover crops in relation to soil fertility and fruit tree nutrition. The effect of grass on the uptake of soil and fertiliser phosphate by Malling I rootstocks. *J. hort. Sci.* (in the press).

(10) Bennett, S. H. and Thomas, W. D. E. (1953). Experiments on the absorption and fate of a systemic insecticide bis (bisdimethylamino phosphonous) anhydride in plants. *Proc. Isotopes Techniques Conf., Oxford*, 1951, **1,** 439.

(11) —— and —— (1953). Experiments on the absorption and fate of a systemic insecticide bis (bisdimethylamino phosphonous) anhydride in plants. *Trans. IX Int. Congr. Ent.*, **1,** 981.

(12) Glynne Jones, G. D. and Thomas, W. D. E. (1953). Contamination of nectar with the systemic insecticide schradan. *Nature*, **171,** 263.

(13) —— and —— (1953). Experiments on the possible contamination of honey with schradan. *Ann. appl. Biol.*, **40,** 546.

(14) Batt, R. F., Bennett, S. H. and Thomas, W. D. E. (1954). The absorption, translocation and breakdown of schradan applied to leaves, using ^{32}P labelled material. Part I. Experimental Techniques. *Ann. appl. Biol.*, **41,** 475.

(15) Bennett, S. H. and Thomas, W. D. E. (1954). The absorption, translocation and breakdown of schradan applied to leaves using ^{32}P labelled material. Part II. Evaporation and Absorption. *Ann. appl. Biol.*, **41,** 484.

(16) Thomas, W. D. E. and Bennett, S. H. (1954). The absorption, translocation and breakdown of schradan applied to leaves using ^{32}P labelled material. Part III. Translocation and breakdown. *Ann. appl. Biol.*, **41,** 501.

THE FUNGICIDAL PROPERTIES OF COAL TAR DISTILLATES: PROGRESS REPORT.

By G. V. COLES and R. J. W. BYRDE.

Introduction.

Coal tar distillates consist of complex mixtures of acidic (mainly phenolic,) neutral (largely hydrocarbon) and basic (principally nitrogen bases) fractions, boiling over a wide range. The neutral oil and tar acid fractions have already found valuable applications in agriculture and horticulture; neutral tar oil boiling above 230°C. forms the basis of the ovicidal winter washes for fruit trees (1), while tar acids (boiling range 250–290°C.) have been recommended for potato haulm destruction (2). Lower boiling tar acids (cresylic acids) are used for soil sterilization, in which fungicidal properties contribute to their effect. In Malaya, Ceylon and elsewhere, tar preparations have been used for many years (3, 4) to control diseases of the rubber tree (*Hevea brasiliensis*), in particular the mouldy rot disease of the newly cut tapping panel caused by the fungus *Ceratostomella fimbriata* (Ell. and Halst.), Elliot.

Little is known of the efficiency of the various coal tar constituents against plant pathogens. In Malaya, since 1931, proprietary materials have had to pass field tests in order to be approved officially for the treatment of mouldy rot (5). Large differences in effectiveness have nevertheless been found among approved products (6). At the request of the Rubber Research Institute of Malaya, work was undertaken to characterize more definitely the fungicidal constituents of tar in order to obtain a chemical basis for the prediction of performance.

Experimental.

The fungus *C. fimbriata* was cultured from infected trees in Malaya and sent to Long Ashton.

Three tar preparations designated A, B and C, used in Malaya, were sent for examination to Long Ashton. In plantation tests in Malaya, A was the least effective, B was intermediate, and C was the most effective in controlling the disease. A and B were single-phase oil formulations which emulsified spontaneously on mixing with water, while sample C was an emulsion containing about 50% water.

Method of bioassay.

The method adopted for laboratory assay was a development of that described by Crowdy (7), standardized as follows.

A sterile peptone-agar medium was prepared with the composition :—

Peptone 10 g.	Calcium chloride 0·1 g.
Dextrose 40 g.	Ferric chloride 0·02 g.
Potassium dihydrogen phosphate 6·8 g.	Agar 30 g.
Magnesium sulphate ($7H_2O$) 2·5 g.	Water to 1 litre.

The pH of the medium was adjusted to 5·3.

The fungicide, suitably formulated, was added to a 50 ml. portion of the liquid medium at 45–55°C. to give the required concentration, and four petri dishes were poured from the mixture and allowed to set. Controls, and "blank" tests for formulating materials, were included. From cultures of the fungus, incubated for about 10 days on the same peptone-agar medium, 4 mm. discs of mycelium were cut with a sterile No. 1 cork-borer. The dishes containing the materials to be tested were inoculated with the discs of mycelium, and placed in random order in an incubator at 25°C. The mean diameter of each culture was determined by measurement along 2 previously marked diameters after 2 days and again after 4 days of incubation. The effect of each treatment was assessed as the mean percentage inhibition of growth of the fungus over the 2 to 4 day period.

Comparison between laboratory and plantation tests.

Assessment by this procedure arranged the proprietary materials in the same order as had been found (6) in the plantation trials (Table I).

TABLE I.

COMPARATIVE PERFORMANCES OF COMMERCIAL COAL TAR FUNGICIDES IN LABORATORY AND PLANTATION TESTS.

Fungicide	Agar Method, 2–4 day period		Malaya field trial (5% concentration)	
	Concentration p.p.m.	Inhibition per cent.	Season	Efficiency Rating
A	400	65	1947	51
	200	39	1948	5
	100	24·5	—	—
B	400	65	1947	50
	200	33·5	1948	28
	100	27	—	—
C	400	97·5	1947	100
	200	54·5	1948	100
	100	30	—	—
	Significant Differences :— P = 0·05 .. 11 % P = 0·01 .. 14·5 % P = 0·001 .. 19 %			

Fractionation and tests of fractions.

A preliminary separation of the materials A, B and C into acidic, basic and neutral constituents was made by modifications of the method described for the analysis of Tar Oil Winter Washes (8). Water contents were determined by the Dean and Stark method. The results are shown in Table II.

The fractions were insoluble and non-dispersible in water and had to be emulsified before bioassay. After tests with different emulsifiers, a method of

TABLE II.

PERCENTAGE COMPOSITION OF COMMERCIAL COAL TAR FUNGICIDES.

Material	Neutral Oil	Tar Acids	Tar Bases	Water	Emulsifier, etc.*
A	66·6	9·3	2·1	6·9	15·1
B	64·2	18·2	2·3	5·0	10·3
C	25·5	22·4	1·0	49·8	1·3

*By difference.

emulsification was found that was equally applicable to all the acidic, basic and neutral fractions examined.

To prepare a material for test at 100 p.p.m. in agar, a little more than 0·5 g. (x g.) of the material was weighed into a 100 ml. graduated flask. 20 x ml. of a benzene solution containing 7·5 per cent. (v/v) of Triton X 155 and 5 per cent. (v/v) of Triton B 1956 were then added from a burette, and the flask shaken to dissolve the material. About three volumes of water were added, the flask was shaken vigorously for about a minute to obtain a satisfactory emulsion, and the contents made up to volume. The amount of emulsion required to give 100 p.p.m. of material in the agar was then added to the liquid medium from a sterile 1 ml. pipette. For tests at higher levels of dosage, the quantities of materials and emulsifiers taken were adjusted to suitable multiples of x so that the proportion of emulsion present in the agar was always of the same order. The emulsions were prepared 24 hours before use to become " self-sterile " ; they mixed readily with the liquid agar and remained stable for some weeks. The emulsifiers caused no inhibition of growth of the fungus at concentrations equivalent to 400 p.p.m. of the test materials.

The results of laboratory bioassay of the fractions separated from the commercial fungicides are shown in Table III.

TABLE III.

COMPARATIVE PERFORMANCES OF FRACTIONS OF COMMERCIAL FUNGICIDES. PERCENTAGE INHIBITION AT 100 P.P.M. (AGAR METHOD, 2–4 DAY PERIOD).

Fractions	Fungicide			Significant Differences		
	A	B	C	P = 0·05	P = 0·01	P = 0·001
Neutral Oil	17	20·5	31	13·5	18	23·5
Tar Acids	65	81	100	14	19	25
Tar Bases	61·5	52	—	27	36	46·5
Emulsifiers, etc. ..	0	2	0			

In view of the small amounts of tar bases found in the materials examined (see Table II), main attention was then focused on the neutral oil and tar

acid fractions. Distillation curves were determined by modifications of the standard Distillation Test for Creosote Oils (9) and these are shown in Figures 1 and 2. The amount of fractionation occurring in such a distillation is small, with poor separation of the components of a complex mixture. To determine whether future work involving fractional distillation would be justified, however, the distillate of each material was collected in separate portions and these were bioassayed. The results are shown in Figures 3 and 4.

It appeared from the results shown in Table III, and from the plantation results when correlated with analysis, that the most fungicidal component of the materials was the tar acid fraction ; and from the results shown in Figures 2 and 4 that the higher-boiling tar acids were of most value. To check these conclusions, examination was made of samples of tar acids and of tar distillates containing high proportions of neutral oil, obtained through the courtesy of the Coal Tar Research Association.

Examination of Tar Acids and Neutral Oil Distillates.

The materials as received were first bioassayed by the agar method ; the results are given in Table IV.

TABLE IV.

COMPARATIVE PERFORMANCES OF NEUTRAL OIL DISTILLATES AND TAR ACIDS. (AGAR METHOD, 2–4 DAY PERIOD).

Material	Inhibition at 100 p.p.m. (per cent.)
Tar Oil Distillate 1 ..	36·5
Tar Oil Distillate 2 ..	24
Cresylic acids	36·5
High boiling tar acids ..	53
Significant Differences :—	
P = 0·05	10
P = 0·01	13·5
P = 0·001	17·5

Analysis of the tar oils by the method previously used (8) gave the results shown in Table V.

TABLE V.

PERCENTAGE COMPOSITION OF NEUTRAL OIL DISTILLATES.

Material	Neutral Oil	Tar Acids	Tar Bases
Tar oil distillate 1	90·6	3·2	6·2
Tar oil distillate 2	90·2	3·0	6·8

The boiling ranges of the tar acids, determined as before (9), are shown in Figure 5, where they are compared with that of commercial sample C.

The high boiling tar acids (D), the tar oil distillate 1 (F) and a blend of equal amounts of each (E) were compounded as emulsions containing approximately 50% of water, and after laboratory assay were sent to Malaya for plantation trials at the Rubber Research Institute. The method of plantation testing was that used previously (6). The comparative assessments of the emulsions in field and laboratory are shown in Table VI.

TABLE VI.

COMPARATIVE PERFORMANCES OF LABORATORY PREPARED FUNGICIDES IN LABORATORY AND PLANTATION TESTS.

Fungicide	Water Content % wt.	Agar method, 2–4 day period		Malaya field trial	
		Concentration p.p.m.	Inhibition per cent.	Concentration per cent.	Efficiency Rating
D ..	53·3	400	98·5	5	98
		200	69	2	72
E ..	53·0	400	93	5	94
		200	69	2	57
F ..	50·9	400	77·5	5	36
		200	41	2	24
C for comparison	—	—	—	5	98
		Significant Differences :— P = 0·05 .. 11·5% P = 0·01 .. 15·5% P = 0·001 .. 20·5%			

The materials were also assessed in Malaya for phytotoxic action (burning of the tree bark). Material F was non-toxic at 20%, D and E were non-toxic at 10% but slightly toxic at 15%.

The results confirm the fungicidal value of the high-boiling tar acids and show these to be non-phytotoxic at double the concentration needed for the control of the mouldy rot fungus.

The effect of the method of preparation of the parent tar upon the fungicidal properties of fractions.

It is well known that the chemical nature of coal tars varies considerably with the method of carbonization used. In general, high temperature and long residence-time in the retorts lead to more aromatic tars than lower temperatures and shorter residence-times. Thus the products become increasingly aromatic through the series low temperature (e.g. " Coalite " process) tars, vertical retort and horizontal retort tars, to coke-oven tar.

To determine the effect of this on fungicidal efficiency, samples of neutral tar oils of various boiling ranges from the " Coalite " process were obtained

from Messrs. Coalite and Chemical Products Ltd. Well-fractionated cuts of neutral tar oils distilled in high efficiency columns from typical tars from vertical and horizontal retorts and from coke ovens were supplied by the Coal Tar Research Association. These materials were bioassayed ; the results of typical tests are shown in Figure 6 (a–d).

The results of bioassays with typical whole-tar tar acids and whole-tar tar bases are shown in Table VII.

TABLE VII.

COMPARATIVE EFFICIENCIES OF FRACTIONS OF SOME TYPICAL COAL-TARS.

Material	Tar type		
	Percentage inhibition at 100 p.p.m., 2–4 day period		
	Low temperature	Vertical	Coke oven
Tar acids	23·5	31·5	28·5
Tar bases	—	28·5	37

Some work has been carried out on the effect of distillation range (without regard to tar source) of the tar acids. In Figure 7 (a) are shown the results of assays on a short series of well-fractionated higher-boiling tar acids distilled in a high-efficiency column and supplied by the Coal Tar Research Association. Figure 7 (b) shows the results of assays of a longer series of tar acid fractions distilled in less efficient equipment. Differences in efficiency between comparable fractions were much greater in the cuts from the more efficient fractionation.

Discussion.

The agar plate method has previously been used in the examination of non-volatile fungicides where a linear relationship between growth and time may be obtained. Mathematical analysis of such results is possible. In the case of tar preparations, which are appreciably volatile, the growth-time relationship is no longer linear. Even close-cut distillation fractions are extremely complex, and the components of such fractions may be of different fungicidal value and different volatility. Because of these factors, calculated allowances for volatility effects are impracticable. Nor is it possible to apply mathematical analysis to the results obtained with a range of concentrations of any given fraction. Consequently, the method of assessment of these materials has been based, as already mentioned, on the determination of the degree of inhibition of fungus growth during the period from 2 to 4 days after inoculation. This period has been selected because it has been found that the culture inoculum reaches a steady growth rate after 2 days, and because the following 2 days is a similar interval to that in plantation applications, which are commonly made on alternate days, the tree being tapped on the intermediate day.

The results in plantation trials given by the laboratory-prepared emulsions (Table VI) appear to confirm the earlier indication (Table I) that the laboratory

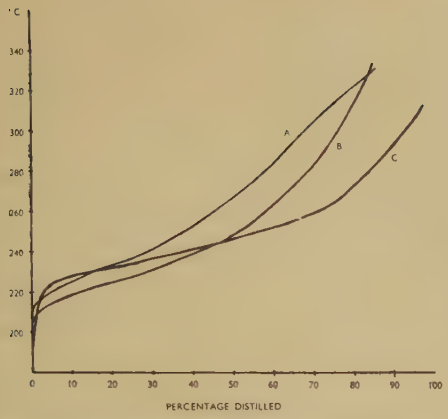


Fig. 1. Distillation curves of neutral tar oils from commercial coal tar fungicides A, B and C.

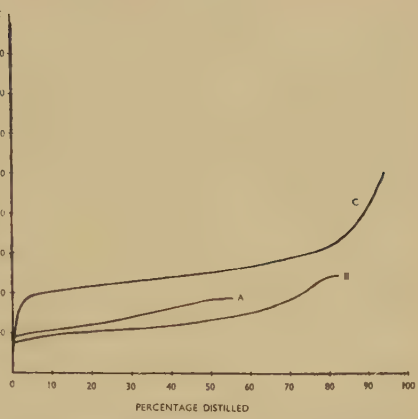


Fig. 2. Distillation curves of tar acids from commercial coal tar fungicides A, B and C.

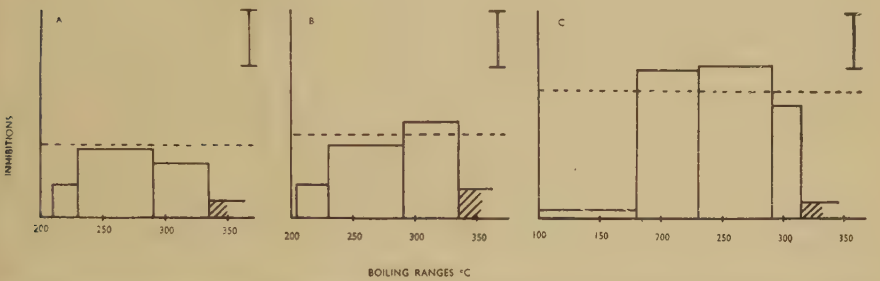


Fig. 3. Relative inhibitions of fungus growth by portions from simple distillation of neutral tar oils from commercial fungicides.

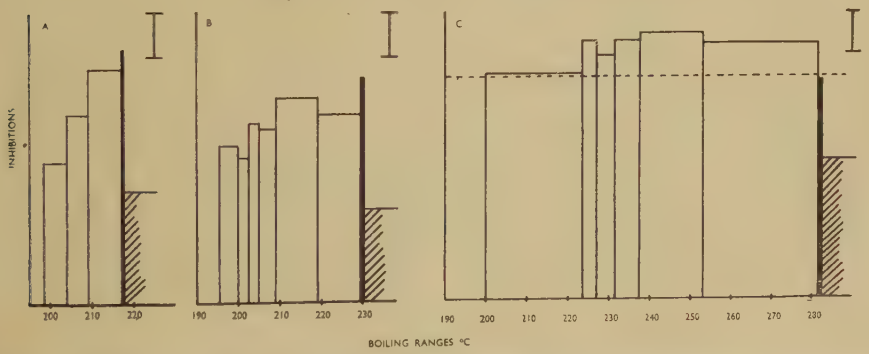


Fig. 4. Relative inhibitions of fungus growth by portions from simple distillation of tar acids from commercial fungicides.

Key to Figures 3 *and* 4 :—

Inhibition level of whole materials
Inhibition by fractions
Inhibition by residues
Inhibition by final distillates
Least significant difference (P = 0·05)

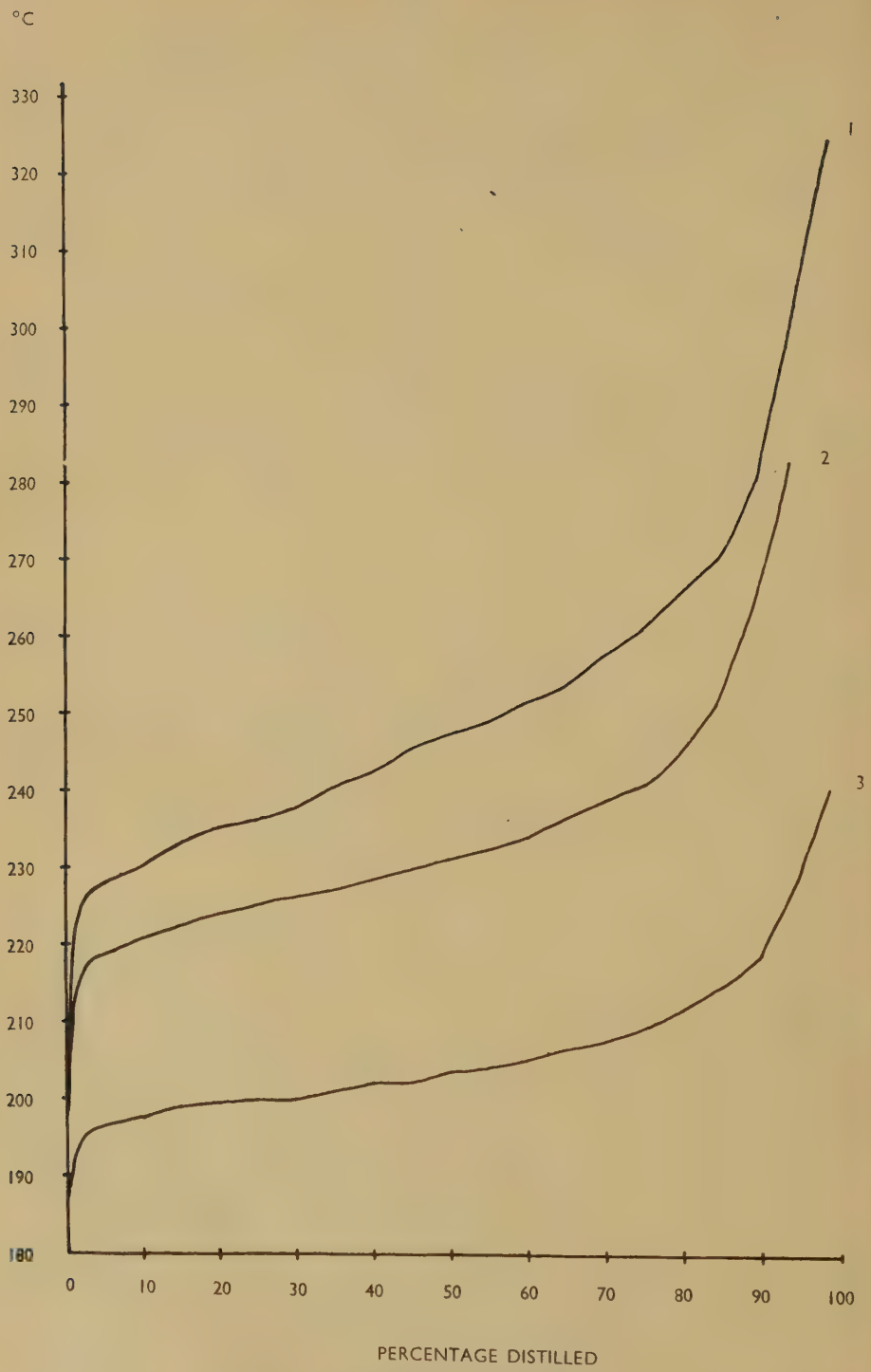


Fig. 5. Distillation curves of tar acids :—
(1) High boiling tar acids.
(2) Tar acids "C."
(3) Cresylic acids.

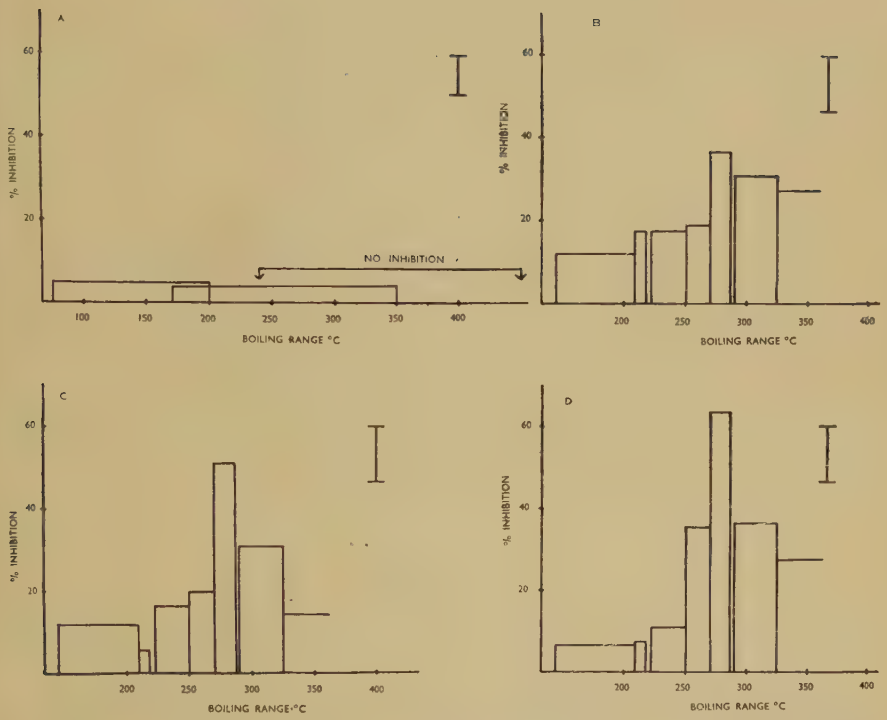


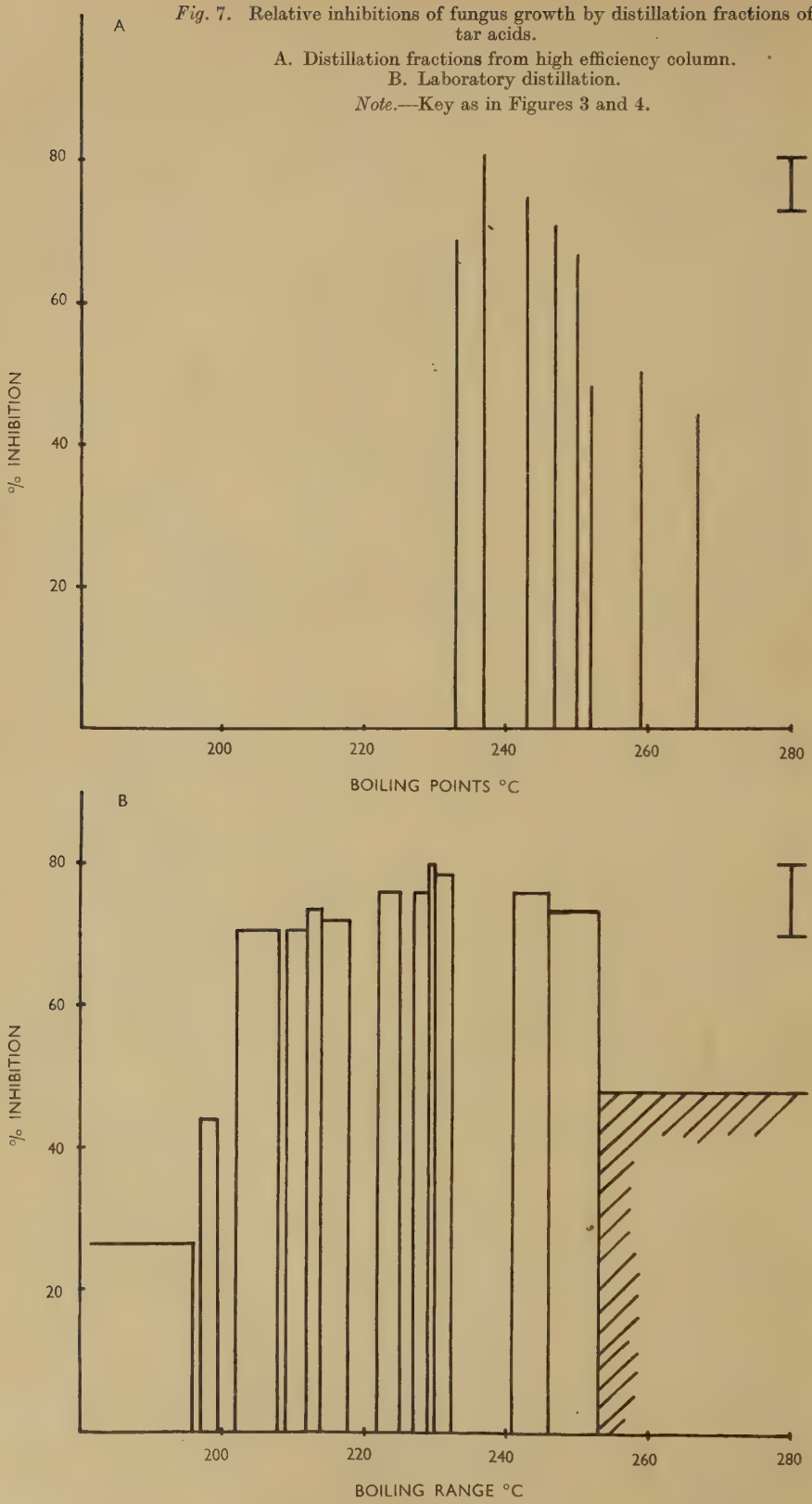
Fig. 6. Relative inhibitions of fungus growth by distillation fractions of different neutral oils.
A. Low temperature tar.
B. Vertical retort tar.
C. Horizontal retort tar.
D. Coke oven tar.

Note.—Key as in Figures 3 and 4.

Fig. 7. Relative inhibitions of fungus growth by distillation fractions of tar acids.

A. Distillation fractions from high efficiency column.
B. Laboratory distillation.

Note.—Key as in Figures 3 and 4.



bioassay may be relied upon to reflect the field performance of materials. Further comparisons, however, are needed. The results given in Table VI also support the contention that the higher boiling tar acids, at least in the materials so far examined, contribute most to field efficiency. The commercial product C clearly owes its superiority over products A and B to the fact that, in spite of its higher water content, it contains a higher proportion of tar acids of greater effectiveness than those in A or B.

The results of the work on distillation show interesting trends. It is clear that significant differences are detectable, in the laboratory bioassay, between portions of efficiently fractionated materials over quite short ranges of boiling points. (See Figures 6b, c and d and Figure 7a). It also seems that these differences are less significant in portions taken from simple distillations. (See Figures 3, 4 and 7b). Further work is required on the effects on field performance of the method of carbonization and of close fractionation, particularly of the tar acids. Little is known as yet about the factors governing phytotoxicity.

The results obtained with well-fractionated neutral tar oils (Figure 6) indicate that in a narrow boiling range—principally the acenaphthene fraction—there are significant increases in fungicidal value as the carbonization methods become more severe and the oils become more aromatic.

Our experience in the chemical separation of the tar distillates into acidic, basic and neutral fractions, has shown that the methods now used might well be improved and work on alternative methods is in progress.

The results reported have been obtained using one species of fungus. Before the picture of the fungicidal action of tar components is clear it will be necessary to extend the investigations to other plant pathogens. The extent to which the fungicidal activities of tar phenols may be correlated with their germicidal and nematicidal properties is also of interest.

Summary.

(1) The fungicidal efficiencies of fractions of coal tar distillates against *Ceratostomella fimbriata*, the fungus responsible for the mouldy rot disease of the rubber tree in Malaya, have been investigated. Maximum efficiency has been found to be associated with the high-boiling tar acids.

(2) Information has been obtained on the extent to which the fungicidal activities of acidic and neutral tar fractions are influenced by boiling range and the method of tar production used.

(3) The assessments of fungicidal effect by a laboratory method of bioassay, which is described, have shown good correlation with the results obtained in Malayan plantation trials.

Acknowledgments.

This work has been carried out with funds provided by the Board of the Rubber Research Institute of Malaya, and this paper is published with the agreement of the Director of the Institute.

We are indebted to Dr. D. McNeil and his colleagues of the Coal Tar Research Association for valuable discussion and for materials, to Messrs. Coalite and Chemical Products Ltd. for materials, and to the Rubber Research Institute of Malaya for helpful collaboration.

Thanks are also due to Mrs. P. M. Fowles and Miss P. M. Jackson for laboratory assistance, and to Dr. J. T. Martin for his interest and support throughout the work.

REFERENCES.

(1) Tutin, F. (1927). *Ann. Rep. Long Ashton Res. Sta.*, 81.
(2) Wilson, A. R., Boyd, A. E. W., Mitchell, J. G. and Greaves, W. S. (1947). *Ann. appl. Biol.*, **34**, 1.
(3) Butler, E. J. and Jones, S. G. (1949). *Plant Pathology*, Macmillan & Co., London, 246.
(4) Sharples, A. (1949). *Diseases and Pests of the Rubber Tree*, Macmillan & Co., London.
(5) Beeley, F. (1936). *J. Rubb. Res. Inst., Malaya*, **7**, 8.
(6) *Rep. Rubber Res. Inst. Malaya*, 1945-48, 151-157.
(7) Crowdy, S. H. (1947). *Ann. Rep. Long Ashton Res. Sta.*, 158.
(8) *Ministry of Agriculture and Fisheries, Tech. Bull.* No. 1, London, H.M.S.O., 1951.
(9) *Standard Methods for testing Tar and its Products*, 2nd ed., S.T.P.T.C., London (1938), 270.

SPRAY APPLICATION PROBLEMS: VII. THE DETERMINATION OF DDT IN PLANT MATERIALS.

By J. T. MARTIN and R. F. BATT.

Introduction.

The problems arising in the use of crop protection materials have been discussed in earlier articles in this series (1, 2). Little is known at present of the factors influencing the levels and biological efficiencies of spray deposits, and methods are required for the assessment of the performance of different types of spraying equipment. Possible hazards to the consumers of crops treated with the more persistent materials have to be borne in mind. The recent report of the Working Party on Toxic Chemicals in Agriculture draws attention to the need for more data on residues in food and for information on the toxicological significance of such residues (3). Much work is needed on these problems, the study of which is dependent upon suitable methods of analysis for deposits. Our objective has been the development of quick methods, using simple chemicals and equipment, applicable to the analysis of large numbers of samples.

The colorimetric method developed by Schechter *et al.* (4) has been used extensively for the determination of small amounts of DDT in plant and animal materials. The principal steps of the method consist of the separation of the DDT by extraction with benzene, the nitration of the DDT, the recovery of the nitrated DDT from acid solution with ether and the development, in benzene solution, of a colour (blue for *pp'*-DDT and violet-red for *op'*-DDT) with sodium methylate.

The method as originally described had certain disadvantages. Fatty material and pigment extracted with the DDT tended to interfere in the nitration process and in the assessment of the colour. The benzene itself, unless completely removed before nitration, also gave rise to colour interference. Additional steps were therefore introduced to overcome these difficulties. Schechter, Pogorelskin and Haller (5) and Davidow (6) incorporated acid treatment to remove fats in the analysis of materials such as milk, while Norton and Schmalzreidt (7), at about the same time as ourselves, used activated alumina to remove wax and pigment from plant extracts. Modifications were also introduced to shorten the analytical procedure; benzene was substituted for ether in the extraction of the nitrated DDT and the analysis was confined to the determination of the insecticidally-important *pp'*-isomer (8, 9).

Reference was made in an earlier report (2) to a rapid method for the detection of DDT in plant material. Further experience with this method has shown its value for the routine quantitative determination of DDT deposits. Carbon tetrachloride is used for the initial extraction, wax and pigment are removed with alumina, the nitrated DDT is separated from the neutralized nitration mixture with carbon tetrachloride and the colour is developed, in carbon tetrachloride solution, with alcoholic potash. The method determines the *pp'*-isomer and has been used successfully in the analysis of foliage, fruits and grain.

The Method of Analysis.

Details of the method are as follows ; notes on steps in the method are given below.

Reagents required.

Carbon tetrachloride. (Redistil before use).
Aluminium oxide, for chromatographic adsorption analysis.
Fuming nitric acid—concentrated sulphuric acid. Mixture of equal volumes.
Potassium hydroxide, 4N. aqueous solution.
Potassium hydroxide, 5 per cent. solution in absolute ethyl alcohol. The solution must be freshly prepared, colourless, and should be filtered clear before use.
Sodium sulphate anhydrous.

Reagents of analytical quality should be used.

The method.

Extract a weighed quantity of the plant material with carbon tetrachloride. Concentrate the extract to about 10 ml. volume by gentle distillation from a hot plate, cool, and pass through a column of 10 g. of alumina, previously wetted with 5 ml. of solvent, supported on cotton wool in a glass tube 150 × 18 mm. diam. constricted at the lower end. Wash through with further 10, 10, 10, 10 and 5 ml. portions of carbon tetrachloride. Concentrate the percolate to about 5 ml. by gentle distillation and finally remove the solvent by passing a stream of dry air over its surface at 40°C.

To the residue add 2 ml. of nitric-sulphuric acid mixture, and heat in a boiling water-bath for 10 minutes. Cool and slowly add 10 ml. of water. Cool again and neutralize the solution by the addition, with swirling and cooling, of 4N. potash solution until litmus paper just turns blue.

Wash the solution with 15 ml. of carbon tetrachloride into a small pear-shaped separating funnel and extract by vigorous shaking for at least 30 seconds. Run the carbon tetrachloride layer into a second separating funnel and re-extract the aqueous layer with a further 5 ml. of carbon tetrachloride. Combine the carbon tetrachloride layers, wash with 3 ml. of water, and run the carbon tetrachloride solution through anhydrous sodium sulphate, supported on cotton wool, into a 25 ml. graduated flask. Wash the separating funnel and sodium sulphate with a little more carbon tetrachloride and make up to volume.

Take suitable aliquots, concentrate these to 0·5 ml. volume with a stream of dry air at 40°C., and to each add 5 ml. of alcoholic potash. Mix well, allow to stand for 5 minutes, and compare the intensities of the colours produced with those of standards prepared from pure *pp'*-DDT or with those given in the standard DDT disc, using the Lovibond Comparator and a 5 mm. cell. Calculate the DDT as parts per million (p.p.m.) of plant material.

Apparatus with ground-glass connections should be used throughout the method.

Initial extraction.

Carbon tetrachloride is preferred as the solvent since it extracts the DDT with a minimum of pigment and gives no risk of colour interference if not completely removed before nitration. Surface deposits may be removed by

successive washing with warm carbon tetrachloride and decantation from a beaker. Alternatively, when convenient, extraction may be made by continuous hot percolation with carbon tetrachloride. Ether may also be used for the percolation, the solvent then being removed from the extract and the residue taken up in carbon tetrachloride. Suitable quantities to take for analysis are 5–10 g. of foliage, 25–50 g. of soft fruits and 25–50 g. of grain.

The possibility of loss of DDT during the hot extraction and distillation processes has been investigated. No loss was found when a known amount of DDT was heated under reflux for two hours in a carbon tetrachloride extract of grain, followed by distillation to low volume. The procedure of washing the column recommended in the method was found to be satisfactory for the recovery of amounts of DDT up to 2 mg.

Nitration.

Following the removal of most of the fatty material by the alumina, the nitration of the DDT proceeds smoothly and quickly. Tests of the effect of different DDT nitration periods from 2 minutes up to 1 hour showed that the reaction was largely completed in 2 minutes and that 10 minutes was ample, in contrast to 1 hour recommended in the Schechter method. Wichmann *et al.* (10) have shown that if no organic matter is present a nitration period of 15 minutes in the Schechter method is adequate. With most materials, the nitration mixture after the addition of water remains clear if less than about 0·05 mg. DDT is present. Quantities of DDT above 0·05 mg. are indicated by an opalescence passing at higher levels to a precipitate. If little or no cloudiness develops, the whole of the carbon tetrachloride solution of the nitrated material should be taken for the colour development; if there is an appreciable cloudiness or precipitate, its extent should be used as a basis for deciding upon suitable aliquots for the test.

The product resulting from the nitration of *pp'*-DDT under the conditions of the test is believed to be the tetra-nitro derivative, 1:1:1-trichloro-2:2-di-(4-chloro-3:5-dinitrophenyl)ethane. To test this further, the tetra-nitro compound was prepared from pure *pp'*-DDT by the method of Backeberg and Marais (11). The product, after recrystallization from dioxan, was obtained as greenish crystals. (*Melting-point* found 219–220°C.; Backeberg and Marais give 218·5–219·5°C. *Chlorine content* found 33·5%; theoretical 33·2%). Aliquots of a solution of the compound in dry acetone were taken, the solvent was removed, the residues were taken up in carbon tetrachloride and alcoholic potash was added. The colours then produced closely matched those given by equivalent amounts of *pp'*-DDT taken through the method. There is thus little doubt that the product formed in the nitration process in the method is 3:3′:5:5′-tetra-nitro-DDT.

Extraction of the nitrated DDT.

The nitrated DDT, precipitated from the nitration mixture by the addition of water, may be extracted by ether, carbon tetrachloride or benzene. Following this step, any pigment present needs to be removed along with the occluded acid to avoid colour interference on the later addition of the alcoholic potash. This may be done by washing the solvent extract of the nitration mixture with alkali or, alternatively, by neutralizing the acid nitration mixture before solvent extraction.

An investigation was made to find the most suitable solvent and to determine whether the extraction of the nitrated DDT should be made from an acid or neutralized solution. Ether was rejected because of its occlusion of water, which was difficult to remove completely. Carbon tetrachloride was preferred to benzene ; the manipulations needed were reduced to a minimum, and as much as 2 mg. DDT was recovered satisfactorily using the quantities of solvent recommended in the method. No differences were found in the intensities of colour produced following ether or carbon tetrachloride extraction of the nitrated DDT from the fully acid, half-neutralized, neutral or slightly alkaline mixture after nitration. The efficiency of extraction was also independent of temperature. The procedure recommended in the method was adopted because of its convenience ; if carbon tetrachloride extraction from acid medium is used, one washing (with 2 per cent. potash) is needed to remove pigment and occluded acid, in contrast to about four washings that are needed if ether extraction is used.

The development of the colour.

The blue colour is given on the addition of alcoholic potash to nitrated DDT in carbon tetrachloride, alcohol, ether or benzene solution. Alcoholic potash is preferred to sodium methylate ; it is prepared more conveniently, and unlike sodium methylate, the concentration of potash is not critical. In tests, colours of equal intensity were given with potash at 3·3, 5·0 and 6·7 per cent. concentrations in alcohol. The alcoholic potash should be added as soon as possible to the final solution of the tetra-nitro-DDT in 0·5 ml. of carbon tetrachloride. If crystals separate from the carbon tetrachloride solution the test should be rejected since a low value may be obtained.

The colour is fully developed after 3 minutes. At high levels of DDT, the colour persists for some ten minutes, but at low levels it commences to fade more quickly. A slight yellow component of the colour fades at the same rate as the blue. Under the conditions of the test, a distinct colour is given by 0·005 mg. DDT.

The preparation of standards.

A suitable range of standard colours may be prepared concurrently with the treatment of the materials under test as follows :—

Make a solution of 0·01 per cent. *pp'*-DDT in carbon tetrachloride. Take 10 ml., remove the solvent by passing a stream of dry air over its surface at 40°C., nitrate and proceed with the method as described to obtain a solution of the nitrated DDT in 25 ml. carbon tetrachloride. Take aliquots equivalent to 0·025, 0·05, 0·075, 0·10, 0·15, 0·20 and 0·25 mg. of DDT, reduce the volumes to 0·5 ml. with a stream of dry air at 40°C., and develop the colours by the addition of 5 ml. of 5 per cent. alcoholic potash.

For convenience a standard disc, giving the colour intensities produced over the range 0·025 to 0·35 mg. DDT, has been prepared in collaboration with Tintometer Ltd. of Salisbury, Wilts., from whom it is available. The disc has been standardized on the intensities of the colours produced, in the hands of two workers, by *pp'*-DDT (melting-point 108·5°C.) alone and by *pp'*-DDT added to grain extract. All the tests at equivalent levels of DDT were in close agreement (Fig. 1). In many trials using foliage, soft fruits and grain free from DDT the final solutions were colourless.

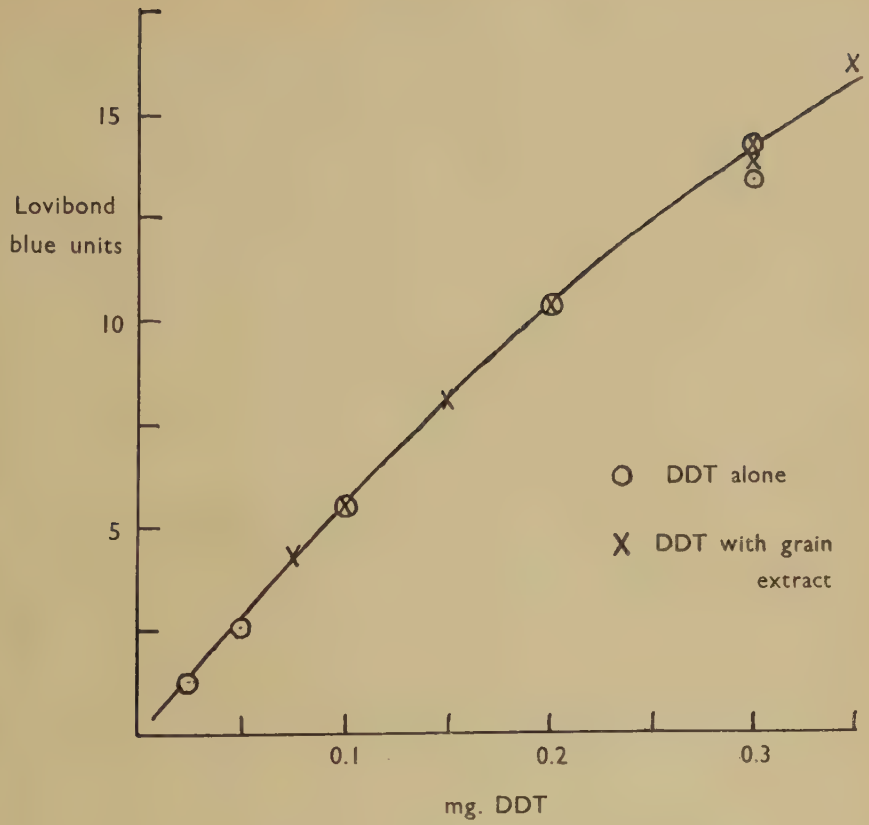

15
Lovibond
blue units
10
5
0.1
0.2
0.3
mg. DDT
DDT alone
DDT with grain
extract

Fig. 1.

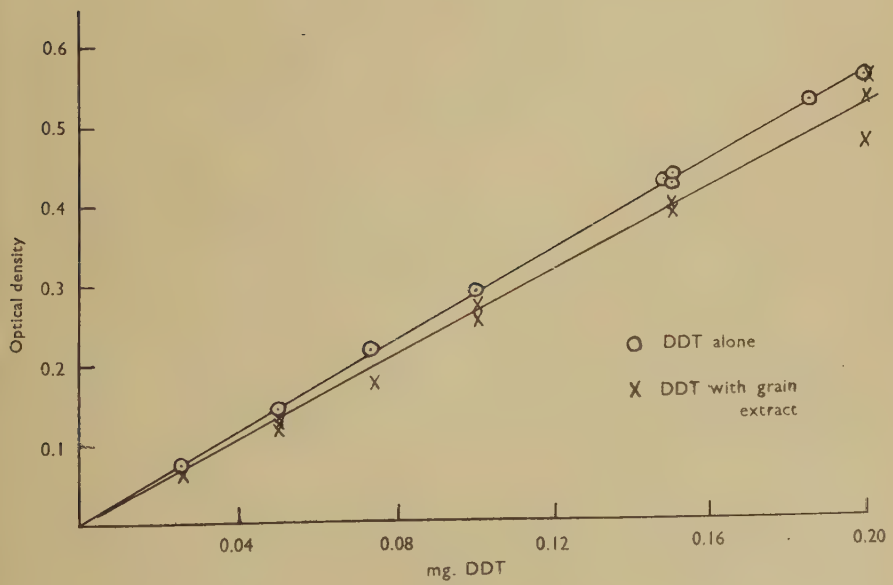

0.6
0.5
0.4
0.3
0.2
0.1
Optical density
0.04
0.08
0.12
0.16
0.20
mg. DDT
DDT alone
DDT with grain
extract

Fig. 2.

On 50 g. samples, differences in DDT content of 0·5 p.p.m. are detected by the visual methods. In tests requiring a greater degree of accuracy, the Hilger Spekker Photoelectric Absorptiometer has been used. In this case 10 ml. of alcoholic potash were added to the tetra-nitro-DDT in 0·5 ml. of carbon tetrachloride and measurements were made within the range 0 to 0·2 mg. DDT using a 5 mm. cell and Ilford filter 607 (orange) with the instrument set to give a water reading of 0·900. Calibration curves were prepared using *pp'*-DDT alone and with grain extract (Fig. 2). Blank determinations gave the following readings : reagents alone, 0·897 ; 25 g. of grain, 0·890 ; and 50 g. of grain, 0·883. The colour resulting from the DDT was found to be stable for 30 minutes when the cell was covered to exclude air.

In all tests, once the initial extraction has been made, the analysis should be completed with the minimum delay.

The Extent of Penetration of DDT into Foliage and Fruits.

(a) *Foliage.*

Reports have been made from time to time of the penetration of DDT into foliage. Ebeling (12) found that DDT applied in kerosene solution to citrus trees passed readily into the leaf tissue and that the amount absorbed could be reduced by the addition of aluminium stearate to the spray fluid. Barlow and Hadaway (13), in field work on the control of tsetse fly in Uganda, pointed out that there was an appreciable loss of both DDT and BHC through absorption by leaves, the loss being most marked when oil solutions or emulsions were used. The penetration of the insecticides was shown by removing the surface deposits by a standardized procedure of washing with benzene, followed by further extraction of the dried and powdered leaves. The decline in residues with time was followed, and a gradual loss of insecticide was shown from both outside and inside the leaves. The observations of Barlow and Hadaway were extended and confirmed by Symes *et al.* (14) who drew attention to the need, in tsetse fly control, for formulations that would not be absorbed by vegetation. Satyanarayana (15) in work in this country on apple foliage has also demonstrated the penetration of DDT, and has examined the effect of different solvent carriers on the extent of absorption. In the work referred to above, determinations of DDT were made by the hydrolysable chlorine method.

Further tests with DDT have been carried out by us on potato and apple foliage, using the method of analysis described in this paper. Our procedure in recovering residues, similar to that of Barlow and Hadaway, has been to remove surface deposits by successive washings with carbon tetrachloride (in a beaker or with a jet of solvent), to air-dry and powder the leaves and to extract with ether.

Potato foliage was sprayed to run-off with an oil emulsion of DDT at 0·06 per cent. Three days later, the values for surface deposits, in successive washings, were 116, 4 and 5 p.p.m. ; the inside deposit then amounted to 28 p.p.m.

Apple foliage was sprayed to run-off, in mid-August, with two formulations of DDT, a benzol-sulphite lye emulsion (A) and a paste (B), each at 0·1 per cent. DDT. Samples of leaves were taken a few hours after spraying, after 8 days and after 70 days just before leaf-fall. The values for surface and inside DDT deposits were as follows :—

	DDT deposits, p.p.m.					
	Initial.		*After 8 days.*		*After 70 days.*	
Formulation	A	B	A	B	A	B
Surface deposit. 1st washing ..	138	204	30	62	2	9
2nd ,, ..	15	11	4	2	1	2
3rd ,, ..	—	—	2	0	1	1
4th ,, ..	—	—	0	0	—	—
Inside deposit	18	39	25	14	18	14

Over the seventy day period, the surface deposits were largely lost, but comparatively little decline was seen in the inside deposits.

(b) *Fruits.*

The methods of separation of DDT used in the experiments reported earlier (2) were designed to recover deposits exposed on, or occluded in, the wax covering of the fruits. The possibility that some of the DDT might also have passed within the fruits was not investigated at that time, but the matter is clearly of some importance from the consumer hazard point of view. Further tests have therefore been carried out, with grapes and blackcurrants. After the removal of the surface deposits, the fruits were slit open, air-dried at 30–35°C. and extracted with ether.

The grapes, in bunches attached to the vine, were dipped in an emulsion or paste formulation of DDT, each at 0·1 per cent. Little or no inside deposits were found in tests over a period of 28 days, although surface deposits were of the order of 50 p.p.m.

Immature blackcurrant fruits in the field were sprayed to run-off with a benzol-sulphite lye emulsion of DDT at 0·1 per cent. Thirteen days later the fruits, which were still green, showed surface DDT deposits, in successive washings, of 31 and 0·3 p.p.m.; the inside deposit then amounted to 0·7 p.p.m. The experiment was repeated using blackcurrant plants in pots in the glasshouse. Fully-grown ripe fruits were sprayed with DDT at 0·06 per cent. in oil emulsion. Five days later the values for surface deposits, in successive washings, were 25, 0·7 and nil p.p.m.; the inside deposit was 1·5 p.p.m. The results of other tests with apples were of little significance since surface deposits were only of the order of 2 p.p.m.

The results obtained show that in the analysis of fruits successive washing with solvent provides a value closely approximating that of the total DDT content but that with foliage, surface stripping is inadequate and more drastic extraction is needed.

Hadaway and Barlow (16) have made the interesting observation that small amounts of DDT are transferred from the inside of treated leaves to other untreated parts of young coffee and Avocado pear plants. Further work is needed, particularly on the extent of absorption of DDT under different conditions of application and on the possible movement of DDT within the plant.

Acknowledgments.

We are indebted to Mr. G. J. Chamberlin of Tintometer Ltd. for his collaboration in preparing the standard disc, to members of the Government

Chemist's Department for checking the disc and to Miss P. M. Jackson and Mr. J. H. Russell for valuable assistance.

REFERENCES.

(1) Martin, J. T. (1953). *Ann. Rep. Long Ashton Res. Sta.*, 1952, 71.
(2) Martin, J. T., Batt, R. F. and Jackson, Pauline (1953). *Ann. Rep. Long Ashton Res. Sta.*, 1952, 75.
(3) Anon (1953). *Toxic Chemicals in Agriculture : Residues in Food*, London, H.M.S.O.
(4) Schechter, M. S., Soloway, S. B., Hayes, R. A. and Haller, H. L. (1945). *Anal. Chem.*, **17**, 704.
(5) Schechter, M. S., Pogorelskin, M. A. and Haller, H. L. (1947). *Anal. Chem.*, **19**, 51.
(6) Davidow, B. (1950). *J. Assoc. off. Agr. Chem.*, **33**, 130.
(7) Norton, L. B. and Schmalzreidt, Barbara (1950). *Anal. Chem.*, **22**, 1451.
(8) Downing, C. and Norton, L. B. (1951). *Anal. Chem.*, **23**, 1870.
(9) Pontoriero, P. L. and Ginsburg, J. M. (1953). *J. econ. Ent.*, **46**, 903.
(10) Wichmann, H. J., Patterson, W. I., Clifford, P. A., Klein, A. K. and Claborn, H. V. (1946). *J. Assoc. off. Agr. Chem.*, **29**, 188.
(11) Backeberg, O. G. and Marais, J. L. C. (1945). *J. chem. Soc.*, 803.
(12) Ebeling, W. (1945). *J. econ. Ent.*, **38**, 689.
(13) Barlow, F. and Hadaway, A. B. (1948). *Bull. ent. Res.*, **38**, 335.
(14) Symes, C. B., Hadaway, A. B., Barlow, F. and Galley, W. (1948). *Bull. ent. Res.*, **38**, 591.
(15) Satyanarayana, P. (1954). *J. hort. Sci.*, **29**, 112.
(16) Hadaway, A. B. and Barlow, F. (1949-50). *Bull. ent. Res.*, **40**, 323.

SPRAY APPLICATION PROBLEMS: VIII. THE CONTROL OF APPLE AND PLUM APHIDES BY DDT AND BHC SPRING WASHES.

By S. H. BENNETT.

In 1945 (1) DDT was shown to be effective for the control of apple aphides and to be most effective when formulated as an emulsion of high wetting properties; more recently BHC as a wettable powder has been recommended and used commercially. It has also been found (2) that Leaf Curling Plum Aphid can be controlled by DDT. This account describes the results obtained by the application of DDT and BHC emulsions and a BHC wettable powder to apple and plum trees.

Apple Aphides.

The Green Apple Aphid (*Aphis pomi* Deg) was the main aphid species present on the trees used for experiment in 1953; some Rosy Apple Aphid (*Sappaphis plantaginea* (Pass.)) was also present. The period of aphis hatch was recorded by counting daily the number of aphides on each of 200 selected buds on 8 Worcester Pearmain trees. The hatching period occurred from March 17th to April 1st with a peak hatch on March 25th, which coincided with the bud burst of Worcester.

Assessment of the extent of infestation was made by recording the number of flower trusses infested with aphides on approximately 100 trusses from each of a number of trees in each treatment. Only in one instance was the degree of aphid infestation on individual flower trusses recorded; elsewhere infestation was judged by the presence of aphides, irrespective of their number. Recording in the main experiment was made at the advanced pink bud stage when the flower stalks had separated sufficiently to allow accurate counting of aphides feeding on the flower-truss.

Where emulsions were used the active material was dissolved in benzene and emulsified with an equal volume of 20% sulphite lye. A concentration of 0·25% benzene in the diluted spray was used throughout the experiments.

Experiment I.

A comparison of DDT and BHC emulsions was made in an experiment carried out on 3 rows of young bush apple trees. Each row contained 10 trees of new unnamed varieties: 3 trees at one end of each row were sprayed with DDT emulsion (0·05% DDT); 3 trees at the other end of each row were sprayed with BHC emulsion (0·014% gamma isomer*); 4 trees in the centre of each row were left unsprayed and used as controls. Drenching sprays were applied on March 16th, at the commencement of the hatch of aphid eggs. All the flower trusses were examined on each tree on March 30th; the numbers infested are recorded in Table I.

The results show that both treatments, applied at the commencement of aphid hatch, considerably reduced the percentage of trusses infested with aphides. BHC was the more effective material.

*Concentrations of BHC are expressed as percentages of the gamma isomer throughout the paper.

TABLE I.

APHID INFESTATIONS.

Treatment	No. of trees	Total No. trusses examined	% Trusses infested
Control (unsprayed) ..	6	275	74·2
0·05% DDT emulsion ..	9	406	10·1
Control (unsprayed) ..	6	301	42·5
0·014% BHC emulsion ..	9	450	0·4

Experiment II.

In this experiment the following treatments were applied to a block of bush Worcester Pearmain trees :—

1. DDT Emulsion = 0·05% DDT.
2. ,, ,, = 0·025% DDT.
3. BHC ,, = 0·014% BHC.
4. BHC ,, = 0·007% BHC.
5. Mixed BHC and DDT Emulsion = 0·05% DDT. 0·014% BHC.
6. Mixed BHC and DDT Emulsion = 0·025% DDT. 0·007% BHC.
7. Benzene sulphite lye check = 0·25% Benzene.

The experimental lay-out is shown in Fig. 1. Plots C1–7 represent unsprayed control trees.

In all sprays di-octyl sodium sulphosuccinate at 0·025% was added as a wetter. The washes were applied on April 7th when aphid hatch was complete and the buds were in the early- to mid-green cluster stage. Drenching sprays (4–5 gal. per tree) were applied. The weather conditions were good at the time of application and the wash dried rapidly.

The aphid infestations were recorded on April 28th at the late pink bud stage using the method described for Experiment No. I ; the results are given in Table II.

TABLE II.

RECORD OF APHID INFESTATIONS.

Plot number	1	C_1	2	C_2	3	C_3	4	C_4	5	C_5	6	C_6	7	C_7
Total no. trusses examined	504	443	533	500	514	427	521	482	500	488	467	500	476	430
% infestation ..	0·2	52·6	0·0	62·9	0·0	50·6	0·0	49·0	0·0	54·9	0·0	62·4	20·8	74·0

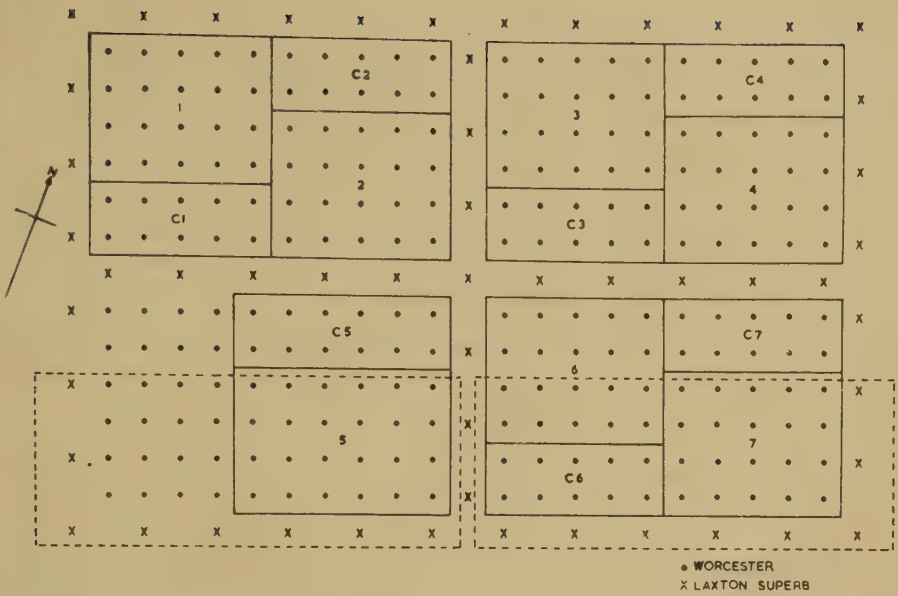


Fig. 1. Lay-out of Experiment II.

All the insecticide treatments gave a very high control of aphides, even at the lower concentrations. The benzene/sulphite lye/succinate check spray also provided some control of aphides, as shown by the relative amounts of infestation on Plots 7 and C_7. In Table III the degree of infestation on these two plots has been placed in four categories as follows : O = No aphides ; L = Light infestation ; M = Moderate infestation ; H = Heavy infestation.

TABLE III.

DEGREE OF APHIS INFESTATION IN PLOTS 7 AND C_7.

Treatment	Total No. of trusses	% infestation			
		O	L	M	H
7	476	79·2	10·7	5·0	5·1
C_7	430	26·0	25·8	16·3	31·9

The results show that the benzene/sulphite lye/succinate solution not only reduced the number of infested trusses, but also the degree of infestation, though the control was inadequate.

Experiment III.

An experiment was carried out to determine the value of BHC applied with and without an additional wetter at the pink bud stage for the control of aphides : lime sulphur was added to these sprays. Two plots shown within the dotted lines on Fig. 1 and cutting across previous treatments 5, 6, C_6 and

7 were sprayed on April 30th with BHC commercial wettable powder containing 13 per cent. gamma BHC. The wash was applied at a concentration equivalent to 0·013% BHC and contained its own wetter + 1·0% lime sulphur. Additional wetter (0·025% di-octyl sodium sulphosuccinate) was incorporated in the spray applied to the plot east of the central barrier row. At the time of spraying the blossom was in the late pink bud stage, with a few king flowers open; the aphides were multiplying rapidly, as viviparous breeding had commenced about a week earlier. A drenching spray was applied at the rate of approximately 7 gal. per tree.

The infestations were recorded on May 9th in the manner previously described. Records were made on the same trees in Plots C_6, 7 and C_7 that were used for the results given in Tables II and III. On the west plot counts were made on trees to the west of 5, and control counts on C_5 and trees in the same row to the west. The results are given in Table IV.

Table IV shows that a very high control of aphides was obtained at late pink bud stage with BHC wettable powder, with and without additional wetter.

From the results of these three experiments it will be seen that BHC at a concentration of 0·013–0·014% gamma isomer gave a satisfactory control of aphides when applied over a period extending from bud burst (commencement of aphid egg hatch) to the late pink bud blossom (aphid multiplication) stage. BHC at 0·007% gamma isomer applied at early to mid-green cluster stage also gave a satisfactory control, but 0·05% DDT applied at the commencement of, and before the completion of, aphid hatch was not satisfactory.

TABLE IV.

APHIS INFESTATION COUNTS.

Treatment		Total No. trusses	% infestation
BHC Wettable powder equivalent to 0·013% BHC + 0·025% di-octyl sodium sulphosuccinate + 1·0% lime-sulphur ..	7	538	0·0
	C_6	534	0·0
Control	C_7	508	57·8
BHC Wettable powder equivalent to 0·013% BHC + 1·0% lime-sulphur ..		551	0·7
Control	C_5+	490	25·3

Leaf-curling Plum aphid (*Brachycaudus helichrysi* (Kltb.)).

The Leaf-curling Plum aphid is normally controlled by tar oil or DNC petroleum washes. Some notes on its life history have been published in an earlier report (2), in which it was shown that the insect spends a considerable period of the winter in the fundatrix stage and can therefore be controlled

by spring washes. More detailed observations of the life history of the insect, made in 1952–53, were helpful in deciding the time of application of sprays.

The following washes were tested :—

1. BHC benzene emulsion (0·014% BHC).
2. BHC wettable powder (0·013% BHC).
3. Tar Oil emulsion 3·5% high boiling neutral tar oil.
4. Tar Oil emulsion 0·5% high boiling neutral tar oil.
5. DDT benzene emulsion 0·0% DDT.

A row of 80 standard plum trees, including the varieties Belle de Louvain, Pershore Egg, Victoria, Early Laxton and Burbank, was divided into plots for treatment, with control trees of each variety.

Applications were made as follows :—

Treatments	1, 2, 3 and 4 ;	January 22nd.
,,	1, 2 and 5 ;	February 20th.
,,	1, 2 and 5* ;	March 19th (bud burst).

*0·025% di-octyl sodium sulphosuccinate added.

All materials were applied as drenching sprays, using lance brooms. The level of aphid infestation on the controls was not heavy and the assessment of the effectiveness of the treatments was made in early June when maximum leaf curling had taken place. Extremely effective control was obtained from all the treatments regardless of the time of application, and on none of the treated trees did the infestation amount to more than a few curled leaves. On the unsprayed trees the infestations varied from slight on some of the Pershore Egg variety to very heavy on Early Laxton.

Complete egg hatch had occurred before the first application on January 22nd : all materials therefore acted as contact insecticides and this no doubt accounts for the good control obtained with 0·5% Tar Oil.

The early hatching of the eggs provides a long period over which effective control by spring washes can be obtained. As mature viviparous females are present at bud burst, the population of aphides builds up very rapidly and the aphides conceal themselves in the flower trusses and curled leaves. It therefore seems unwise to delay application much beyond bud burst. Very early application will, however, fail to control eggs of the Mealy Plum Aphid (*Hyalopterus pruni* (Geoffr.)) and the Winter Moths.

Summary.

(1) A satisfactory control of apple aphides was obtained with BHC at 0·013–0·014% gamma isomer applied as an emulsion at early bud burst and at early to mid-green cluster stages, and as wettable powder applied at the late pink bud blossom stage.

(2) BHC at 0·007% gamma isomer and DDT at 0·025% were both effective at the early green cluster stage.

(3) BHC at 0·013%–0·014% gamma isomer both as emulsion and wettable powder, Tar Oil at 3·5% and 0·5%, and DDT at 0·05% as an emulsion have given efficient control of Leaf-curling plum aphid when applied in January, February or March.

Acknowledgments.

Thanks are due to Mrs. E. B. Salway for assistance in recording and to Mr. J. H. Russell for assistance in spraying.

REFERENCES.

KEARNS, H. G. H., MARSH, R. W. and MARTIN, H. (1945). *Ann. Rep. Long Ashton Res. Sta.*, 132.
KEARNS, H. G. H. and MORGAN, N. G. (1950). *Ann. Rep. Long Ashton Res. Sta.*, 123.

SPRAY APPLICATION PROBLEMS: IX. OBSERVATIONS ON THE TIME OF APPLICATION AND INFLUENCE OF SITE OF DEPOSITION OF BHC ON THE CONTROL OF APPLE SAWFLY (*HOPLOCAMPA TESTUDINEA* KLUG.)

By S. H. BENNETT.

Developments of new insecticides and methods of application have made it necessary to investigate their timing and placement for the control of specific insects. Before the advent of the chlorinated hydrocarbons and organic phosphorus compounds, apple sawfly was successfully controlled by nicotine. The success of this treatment depended on accurate timing and very efficient spraying to ensure a thorough wetting of the calyx cup tissue; the nicotine acted as a stomach poison, presumably by combining with the calyx cup tissue which forms the first meal of the newly hatched larvae. The need for a material with a longer range of action, requiring less efficient spraying and greater latitude in timing, was desirable. Of the materials tested for these qualities BHC proved the most promising and has been extensively used at petal fall. The present paper describes field experiments that suggest that BHC applied at the commencement of blossoming markedly reduces the infestation of sawfly; they have also shown that a control of the larvae can be obtained at petal fall without complete wetting of the calyx.

(a) Placement of Insecticide.

The increasing popularity of small-volume methods of application of washes to fruit, in contrast to the conventional method of applying until "run off" occurs, has made it necessary to obtain information on the effectiveness of BHC applied to different sites on the fruitlet for the control of sawfly. Observations were made on the effectiveness of the six treatments listed below applied to fruitlets on bush trees of the variety Worcester Pearmain.

1. Untreated.
2. Check Treatment — sulphite lye benzene emulsion applied at an equivalent concentration to that used in the insecticide emulsions, and sprayed on complete truss until the inside and outside of the blossom were wetted.
3. BHC Emulsion — sprayed on the complete truss as in (2).
4. ,, ,, — applied over each "sting"* on outside of receptacle.
5. ,, ,, — applied to receptacle opposite the "sting."
6. ,, ,, — complete wetting of receptacle of all infested fruitlets in a truss.
7. ,, ,, — applied to inner calyx cup and stamens of "stung" fruitlets in a truss.

*"Sting": the red mark produced at the site of insertion of the ovipositor.

The BHC emulsion for all treatments was prepared from the pure gamma isomer and was used at a concentration of 0·014%* BHC by weight and 0·062% benzene by volume. Treatments 2 and 3 were applied by a small pneumatic hand sprayer; 4, 5, 6 and 7 were applied by placing the insecticide on the selected area with a fine camel-hair paint brush. Each treatment was carried out on individual trees. Two separate series of applications were made, the first on the 15th and the second on the 21st May.

Two random collections of "stung" fruitlets were made to assess the stage of development of the eggs at the time of treatment, the first on the day following the first application (16th) and the second on the day preceding the second application (20th). From the collection made on the 16th, 68 out of a total of 279 eggs showed no larval development and 211 showed some progress in development but not to a very advanced stage. From the collection of 122 eggs made on the 20th, 32 had hatched and the rest showed larval development, with the majority well advanced, including chitinization of the head capsule and mouth parts. Nearly 50% of the eggs would therefore have been hatched by the time the second application was made.

The treated trusses were removed and examined in the laboratory to assess the effectiveness of the treatments. The results are given in Table I. It will be noted that results are recorded under three groups as (1) "stings only" which refer to fruitlets upon which the only visible damage was the initial egg laying scar; (2) "stung and tunnelled" refers to fruitlets where the egg had hatched and the larva had tunnelled into the fruitlet; and (3) "fresh entry" refers to fruitlets which contained larvae but in which an egg had not necessarily been laid. The percentage infestations are therefore recorded excluding the fresh entries (A) and including them (B). Many of the dead larvae were found in the calyx cup cavity, often clinging to the stamens.

The results show that for the first application a reasonable control was obtained in all treatments except 2 and 5. For the second application a less efficient control was obtained in all treatments except 3 and 7. This poorer control suggests that BHC has less effect on the egg near hatching. It would seem probable that treatment 7 and more especially treatment 3 would be the treatments most likely to affect the hatched larvae, as there was greater likelihood of their coming into contact with a treated surface.

The results showed that when application was made before egg hatch, an appreciable control was obtained without complete coverage of the fruitlet.

(b) Timing of Application.

BHC is normally used for the control of the newly hatched larvae. An experiment was carried out to ascertain whether the insecticide could be used to prevent egg laying by killing the adult sawflies.

In laboratory tests adult sawflies were found to be sensitive to BHC deposits. A 2–3 minute exposure on either petals, fruitlets or leaves that had been sprayed 24 hours previously with a BHC wettable powder (0·007% BHC) affected the sawflies within a few hours and resulted in their death. It was also found that sawflies were disturbed by contact with blossom treated with the insecticide 8 days previously, though they were not killed after being allowed to wander over the treated surface for 5 minutes.

*Concentrations of BHC are expressed as percentages of the gamma isomer throughout the paper.

TABLE I.

EFFECT OF PLACEMENT OF INSECTICIDE ON SAWFLY CONTROL.

Treatment No.	Date of application	Total stings treated	Assessment of Results				% Control	
			Stings only	Stung and tunnelled	Fresh entries	Total fruitlets	A	B
1 (Control) ..	15/5	—	—	323		761		
2	„	—	—	190		348		
3	„	—	—	3		423		
4	„	135	132	3	9		97·8	91·1
5	„	106	67	39	7		63·2	56·6
6	„	185	180	5	1		97·3	96·7
7	„	83	75	8	0		90·4	90·4
1 (Control) ..	21/5	—	—	293		907		
2	„	—	—	89		311		
3	„	—	—	7		333		
4	„	102	71	31	6		69·6	63·7
5	„	115	60	55	9		52·2	44·4
6	„	109	90	19	3		82·5	79·9
7	„	91	83	8	10		91·2	80·2

A field trial was carried out on a block of bush trees of Worcester Pearmain divided into 2 plots, each containing 4 rows of 10 trees. To one plot BHC wettable powder (0·007% BHC) containing its own wetter, and to the other the same BHC wettable powder (0·007% BHC) plus additional wetter (0·025% di-octyl sodium sulphosuccinate) was applied on April 30th as a drenching spray at the rate of 7 gallons per tree. The blossom was in the advanced pink bud stage with a few king flowers already open ; the weather during the experiment was dry.

On May 11th and 12th, when 50% of the petals had fallen, counts were made of the number of " stung " fruitlets. Approximately 500 fruitlets on each of 10 trees in each treatment and on 15 unsprayed trees were examined. On June 9th and 10th a second count was made on the same trees. By this time the fruitlets had swollen so much that it was impossible to locate and record the number of " stings." The larvae were entering their second or third fruit, and all tunnelled fruits were recorded as a percentage of the total fruitlets. The results are given in Table II.

The results show that both treatments greatly reduced the number of " stung " fruits and that there was an even greater reduction in the percentage of tunnelled fruits. It was not ascertained whether the reduction in the number of " stung " fruitlets was achieved by killing or repelling the adults. Control

TABLE II.

SAWFLY COUNTS FOLLOWING PINK BUD APPLICATION OF BHC.

Treatment	Counted May 11th & 12th		Counted June 9th & 10th	
	Stung fruit	Per cent. infestation	Tunnelled fruit	Per cent. infestation
BHC Wettable Powder (0·007% BHC) ..	377	7·7	8	0·2
BHC Wettable Powder (0·007% BHC) + 0·025% di-octyl sodium sulphosuccinate ..	193	3·8	2	0·0$_8$
Control	1446	21·2	1341	40·5

trees adjoining the treatments showed no higher infestation than trees 7 rows away from the treatments ; there is therefore no evidence that BHC acted as a repellent, driving the sawflies to neighbouring untreated trees. The decrease in infestation that occurred between the " stung " fruitlets and the tunnelled fruitlets on the treated plots could be explained either by a reduced fecundity of the females or by the residual deposit being sufficient to kill eggs already laid. Not many of these " stung " fruitlets were examined, but dead larvae were found in a few.

These results show that further investigations are desirable.

Summary.

(1) The influence of the site of placement of BHC on developing fruitlets on the control of apple sawfly larvae immediately after emergence is discussed. Good control was obtained without complete coverage of the fruitlet.

(2) When the application of BHC was delayed until after the commencement of egg hatch, only flooding of the calyx cup or complete wetting of the truss gave efficient control.

(3) BHC applied at late pink bud blossom stage to control adult sawflies gave promising results in 1953.

Acknowledgments.

Thanks are due to Mrs. E. B. Salway for assistance in applying the materials and in recording, and to Mr. J. H. Russell for assistance in spraying operations.

SPRAY APPLICATION PROBLEMS: X. THE EFFECTS OF SPRAYING TECHNIQUES ON THE CONTROL OF SOME FRUIT INSECTS.

LANCE AND AIRFLOW MIST SPRAYING.

By H. G. H. KEARNS and N. G. MORGAN.

Introduction.

The high cost of spraying top fruit in the post-war years has encouraged the development of spray application techniques aimed at reducing the labour and time involved.

The first step has been the introduction of so-called automatic machines that use large volumes of wash; by this method labour may be reduced to one third and spraying time to one half of that required for hand lance spraying (1).

The second development, small-volume airflow spraying, is still in the experimental stage in this country. In this technique the volume of water applied may be only one third to one sixth of that used in large volume spraying by lance or automatic machine, with a marked reduction in cost.

Hitherto it has been assumed that, although the volume of water could thus be reduced, the weight of insecticide or fungicide applied per acre must necessarily remain at the same level as that used in large-volume run-off methods, leading to the use of the so-called "concentrates." This assumption may, in part, be due to experience in weed control with growth-regulating substances, where efficiency is largely governed by the amount of active material applied per acre irrespective of the volume of water used.

Experiments were begun in 1952 to investigate the effects on apple scab of small-volume spraying with dilute instead of concentrated materials.

The advantages of this technique would be :—

(1) The cost of active insecticide or fungicide could be reduced to one third to one sixth of that used in large-volume methods.

(2) The use of dilute materials would obviate the risk of crop damage should complete wetting accidentally occur with a material phytocidal when applied in high concentration.

The success attending spring spraying with large volumes of DDT and BHC washes of normal dilutions, as substitutes for winter washing, suggested field trials on the application of these materials by small-volume air-flow methods.

Machinery and Methods.

The experimental small-volume air-flow machine used for the trials was similar in basic design to that described by Kearns and Morgan (3) with the addition of a special "fish-tail" trunking attached to the fan discharge port (Plate (a)). This was designed to produce a wider vertical sweep of air than was possible with the circular port and dispersing cone previously used (2).

On each side of the discharge end of the fish-tail was fitted a $\frac{1}{2}''$ bore copper feed-tube with eight $\frac{1}{4}''$ B.S.P. spray nozzles (4) at 9″ spacing. The

feed-rate of spray fluid could thus be adjusted to suit particular conditions by using one or both feed tubes, by blanking off some of the nozzles or by changing the nozzle discs.

In most of the experiments the travelling speed of the machine was 1½ m.p.h. and the nozzle output was adjusted to apply approximately 100 gallons of spray liquid per acre.* Except on plots with tall dense trees where some hand manipulation of the "fish-tail" trunking was necessary, spraying was automatic, the vertical and horizontal angles of the air-stream being adjusted according to tree shape and wind direction respectively (Plate (b)). Each tree row was sprayed from two opposite sides.

The wetting agent used in all the trials was dioctyl sodium sulphosuccinate (100%) dissolved in acetone, the final dilution being 0·025% succinate.

Trial 1 : *Leaf-curling Plum Aphid.*

A single row of plums (vars. Yellow Egg and Laxton Bountiful) was divided into sections of six trees each and sprayed with a DDT-benzol-lye emulsion including wetting agent on March 19th, 1953, at the bud burst stage when most of the aphid stem mothers had produced young.

Counts were made on 1/5/53 of shoots bearing leaves showing typical curling due to aphid attack. Results are summarised in Table I.

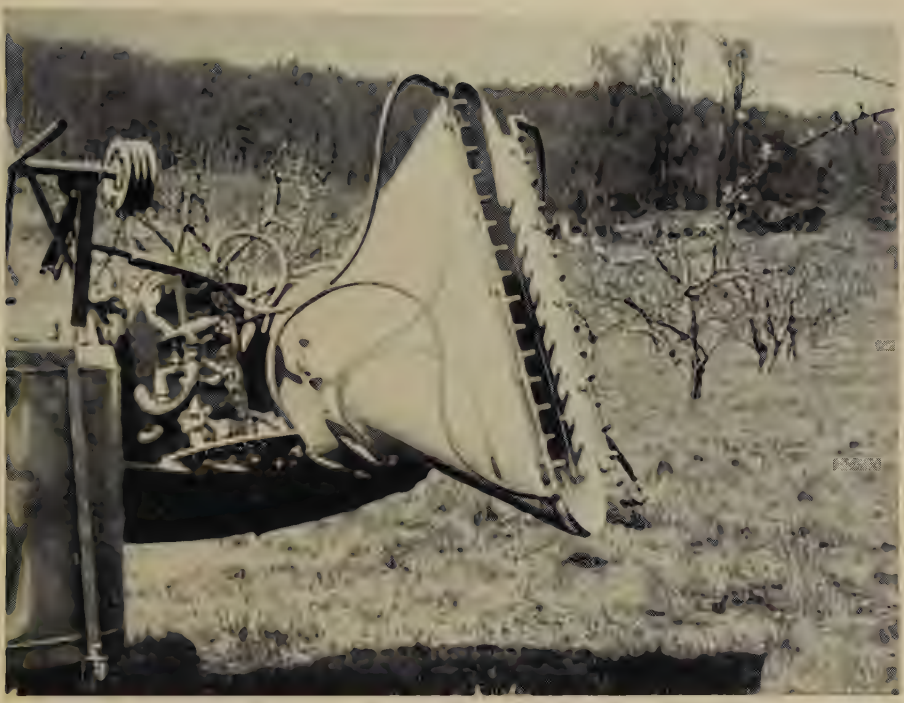
TABLE I.

Section	Spraying method	Concentration of DDT	Gallons wash applied		% Shoots infested
			Per tree	Per acre	
A	Hand lance	0·05%	3	580	<1·0%
C	Air-flow mist	0·05%	1·0	190	<1·0%
D	Air-flow mist	0·25%	1·0	190	<1·0%
B	Unsprayed	—	—	—	50·0%
E	Unsprayed†	—	—	—	50·0%

†Trees received some drift from Section D.

*It should be emphasised that while a high proportion of spray liquid applied through hand lances is directed at the trees, as much as one third of that applied by fully automatic machines may be directed through the spaces between the trees unless these are planted out and shaped to suit the method. Furthermore, some of the small spray droplets used in small-volume spraying may be drifted by wind away from the target and may or may not be deposited on neighbouring trees. The volume per acre quoted as an indication of spraying efficiency is therefore less accurate for automatic than for hand methods. The volume per acre applied by an automatic spray machine depends on throughput per minute, travelling speed, and planting distance only, while that applied by hand depends upon the personal factor coupled with height and density of trees, nature of the target surface, physical characteristics of the spray fluid, wind conditions and other factors.

PLATE (a).



" Fish-tail " trunking (port dimensions 45″ × 7″) with nozzle assembly.

PLATE (b).

Small volume " air-flow " mist spraying of bush apples. The " fish-tail " trunking is adjusted to 45° from the axis of travel and 30° from the horizontal.

Complete control of Plum aphid was thus obtained by hand spraying and by air-flow mist applications of both dilute and concentrated DDT emulsions.

Trial 2 : *Apple Aphides.*

A plot of 18 year old bush apples (var. Cox's Orange Pippin with Worcester Pearmain pollinator) was sprayed by air-flow mist blower with an emulsion containing DDT, BHC (gamma isomer) and wetting agent at the late bud burst stage when all *Aphis pomi* had hatched.

The lay-out of the trial is shown in Fig. 1 and the results are summarised in Table II.

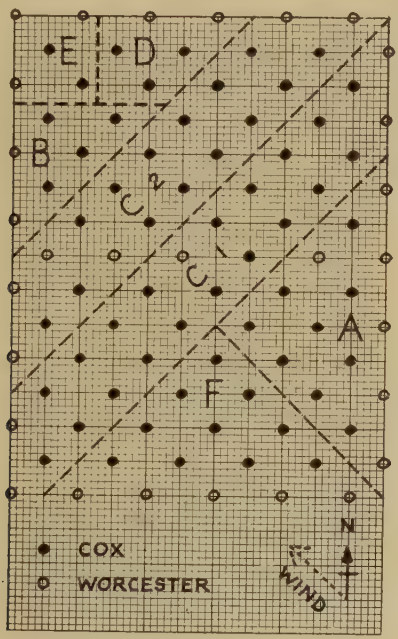


Fig. 1.

The results show complete control of apple aphides by both hand lance " run-off " and air-flow mist spraying methods. No difference in degree of control was observed between air-flow mist spraying with normal concentration and with five-fold concentration of the DDT/BHC emulsion. It is thus possible to obtain control of apple aphides by air-flow mist application of approximately $\frac{1}{4}$ of the volume of water and $\frac{1}{4}$ of the weight of active materials required for hand lance " run-off " application.

Trial 3 : *Fruit Tree Red Spider Mite and Woolly Aphid.*

The same plot described in Trial 2 was sprayed with 1% lime sulphur and wetting agent as shown in Fig. 2 and Table III.

TABLE II.

Block	Spraying method	Concentration of active materials	Volume wash applied		% Blossom trusses infested	
			Gall. per tree	Gall. per acre		
A ..	Hand lance (no drift)	0·05% DDT 0·014% BHC	4·5	434	0·0	+
B ..	Hand lance (drift)	0·05% DDT 0·014% BHC	4·5	434	0·0	+
C1 ..	Air-flow mist	0·05% DDT 0·014% BHC	1·0	96	0·0	+
C2 ..	Air-flow mist	0·25% DDT 0·07% BHC	1·0	96	0·0	+
D ..	Unsprayed (drift)	—	—	—	9·15	*
E ..	Unsprayed (drift)	—	—	—	37·25	*
F ..	Unsprayed (no drift)	—	—	—	73·0	*

+No aphides were found on these blocks after randomised counting of trusses and additional search.

*The lower infestation on the unsprayed blocks which received spray drift was not necessarily due to drift but may represent the natural level of infestation in this part of the plot before it was sprayed.

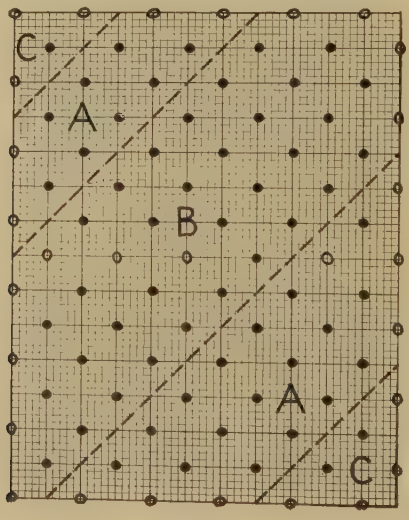


Fig. 2.

A = Large-volume hand lance.
B = Small-volume air-flow.
C = Unsprayed.

TABLE III.

Spraying date	Approximate bud stage	Approximate volume liquid applied (gall.)			
		A		B	
		per tree	per acre	per tree	per acre
4/5/53 ..	Pink bud	6·4	617	1·125	109
21/5/53 ..	Petal fall	5·0	482	1·0	96
28/5/53 ..	10 days after petal fall	5·0	482	0·75	72
15/6/53 ..	3 weeks after petal fall	5·0	482	0·75	91

Visual observation of the results of the above treatments was sufficient to show the following :—

A Slight red spider and woolly aphid infestations.

B, C } Devastating attacks of both red spider and woolly aphid.

The plot had been given two small-volume air-flow applications of DDT emulsion (0·10% DDT) on 21st May and 10th June, 1952, with the intention of increasing red spider infestation for experimental purposes. The indications are that this 1952 DDT spraying had effectively reduced the population of predators of both red spider and woolly aphid with a resulting increase in these two pests in 1953. The above observations show that thorough hand lance application of lime sulphur and wetter controlled both pests but the small volume air-flow method with the same materials failed to do so.

The woolly aphid infestation was later controlled by hand lance application of a BHC emulsion (0·014% gamma isomer) and wetting agent on August 31st, 1953.

Two blocks of Worcester Pearmain were sprayed by hand lance as follows :–

Block	Date	Spray materials	Observations
A	23/5/53	Lime sulphur (1%) + wetter (0·025%)	Slight red
	13/6/53	,, ,, (¾%) + wetter (0·025%)	spider attack
B	26/5/53	Lime sulphur (1%)	Heavy red
	13/6/53	,, ,, (¾%)	spider attack

It is evident that this mite can be controlled by lime sulphur applications provided that an adequate wetting agent is used and that spraying of the lower surfaces of the leaves is thoroughly carried out.

Trial 4 : *Apple Sawfly.*

Air-flow mist applications of a dilute emulsion containing 0·014% gamma BHC, 1% lime sulphur and a wetting agent were made on a plot of Worcester Pearmain on 18/5/53 for the control of apple sawfly. Treatments and results are summarised in Table IV.

TABLE IV.

Spraying method	Volume liquid applied (gall.)		% Fruitlets infested by Sawfly	
	per tree	per acre		
Air-flow mist	1·0	193	13·4	a
Air-flow mist	1·0	193	5·87	a
Unsprayed	—	—	53·0	a
Hand	5·0	480	0·43	b
Unsprayed	—	—	42·6	b

a and b were separate plots.

The results show that a commercial control of apple sawfly was obtained by air-flow mist application of dilute BHC emulsion and wetting agent. Hand lance spraying with the same materials gave complete control.

Summary.

(1) Experiments on the control of apple and plum aphides, red spider and apple sawfly by means of air-flow mist spraying are described.

(2) DDT emulsion gave virtually complete control of leaf-curling plum aphid when applied by air-flow mist spraying using approximately one third of the volume of liquid and one third of the weight of DDT per acre of that used by hand-lance " run-off " methods.

(3) Apple aphides, excluding woolly aphid, were completely controlled by a dilute DDT/gamma BHC emulsion applied at bud burst stage by air-flow mist spraying using approximately one quarter of the volume and active materials per acre required by lance spraying.

(4) Air-flow mist application of an emulsion containing 0·014% gamma BHC at approximately 1 gallon per tree gave a substantial control of apple sawfly.

(5) A devastating infestation of red spider and woolly aphid on apples followed the application by air-flow mist spraying of lime sulphur and wetting agent, whereas the same materials applied by hand lance gave a very high control.

Acknowledgment.

The cost of this investigation was in part defrayed by a grant from the Agricultural Improvement Council, whose help is gratefully acknowledged.

REFERENCES.

(1) Kearns, H. G. H. and Morgan, N. G. (1949). The automatic spraying of top fruit with a spray " mast." *Ann. Rep. Long Ashton Res. Sta.*, 104–110.

(2) Kearns, H. G. H., Marsh, R. W. and Morgan, N. G. (1952). Spray application problems : IV. Preliminary field experiments on the control of apple scab by small-volume sprays. *Ann. Rep. Long Ashton Res. Sta.*, 90–95.

(3) Kearns, H. G. H. and Morgan, N. G. (1950). An experimental " air-flow " small-volume sprayer and duster. Abridged specification. *Ann. Rep. Long Ashton Res. Sta.*, 132–137.

(4) Kearns, H. G. H. and Morgan, N. G. (1949). A lightweight spray nozzle ($\frac{1}{4}''$ B.S.P.) for " small " and " large " volume spraying. *Ann. Rep. Long Ashton Res. Sta.*, 111–114.

SPRAY APPLICATION PROBLEMS: XI. A NOTE ON THE PREPARATION OF A COMBINED DDT-GAMMA BHC EMULSION OF HIGH WETTING PROPERTIES AS A SUBSTITUTE FOR WINTER WASHES.

By H. G. H. KEARNS and N. G. MORGAN.

The use of DDT and BHC as substitutes for winter washes on fruit crops, especially apples, is now established. Variable results have been obtained, however, under commercial conditions, largely due to lack of appreciation of the need to use formulations of high wetting properties in conjunction with efficient spraying. In some cases severe infestations of Red Spider have been associated with the pre-blossom application of high concentrations of DDT.

The control of aphides by DDT can be achieved only by well-timed application of an emulsion of high wetting properties. The most certain results are obtained either by applying the wash coincident with the bud burst stage of Worcester Pearmain when the aphides are exposed on the outside of the buds, or by selecting the advanced green bud stage when the aphides are again exposed on the separated flower stalks. The intermediate stage is less satisfactory as the aphides have then crept between the tightly packed flower buds where they are partially protected from wetting by the spray material.

Apple sucker generally hatches after the aphides; it immediately enters the tightly clustered buds and is much less vulnerable to contact washes. The application of DDT at bud burst may in some seasons be too early to ensure complete control of "caterpillar." The control of capsid is much less dependent upon formulation of materials and upon critical timing of application and it may be applied at any stage from bud burst to pink bud. The concentrations of DDT in suitably compounded emulsions need never exceed 0·025% (i.e. $\frac{1}{4}$ lb. per 100 gallons dilute wash) when used as a substitute for a winter wash and on occasions, during routine spraying, DDT emulsions applied at rates as low as 2 oz. per 100 gallons in combination with lime sulphur have been found to control caterpillar.

BHC wettable powders (13% gamma isomer) and emulsions (99.9% gamma isomer) of fairly good wetting properties both provide a complete control of aphides and sucker with far less critical timing or thoroughness of application than is necessary with DDT, but they do not provide such a high degree of control of caterpillar or capsids. The ready control of aphides and apple sucker by BHC depends upon its ability to disturb the nymphs which, although not touched by the spray liquid, are near the site of deposition. This long range action causes the insects deep in the folds of the bud to creep out and come into contact with the area bearing the spray deposit. The majority of the insects eventually fall from the host plant and die, and some may die and

remain attached to the bud. Experiments showed that an emulsion containing 0·007% gamma BHC (i.e. $1\frac{1}{8}$ oz. per 100 gallons dilute wash) gave complete control of aphides.

The high concentrations of 0·1% DDT (1 lb. per 100 gallons) and 0·2% of 13% gamma BHC (i.e. 0·028% gamma isomer) usually recommended increase the risk of high residual deposits on the tree which, on apples and plums, are undesirable because they increase the duration of toxicity to insect predators.

The ever-increasing costs of spray programmes have centred attention on the need for the more economic use of spray materials by obtaining the maximum results from them. This may be achieved by better formulation and by more efficient methods of application ; thus at Long Ashton experiments on air-flow mist spraying, using small droplets, have shown the need for increasing the contact angle to improve impaction on the target surface.

In view of the differing and, to a large extent, complementary actions of DDT and BHC washes, it appeared a practical step to compound both insecticides in a single emulsion of high wetting properties for field use.

Preparation of the Emulsion of DDT and BHC.

1 lb. DDT (70–75% *pp'* technical grade) and $4\frac{1}{2}$ oz. BHC (99·9% gamma isomer) are dissolved in 2 pints commercial benzol. The solution is emulsified with an equal volume of 20% sulphite lye solution (made from soda sulphite lye of 1·3 S.G. (60° Tw.) by means of a colloid mill or homogeniser. One pint of the stock emulsion is made up to 100 gallons with water together with 4 oz. di-octyl sodium sulphosuccinate (100%) wetting agent. The succinate is only sparingly soluble in water and must first be dissolved in acetone or industrial alcohol.* The wetter plays an important role in ensuring even distribution of the emulsion over the target surfaces of bark, buds, foliage, fruitlets and insects. The emulsion may be stored for long periods without deterioration in galvanised steel containers or new jerricans with intact petrol-proof paint lining ; it should on no account be kept in containers liable to rust. Agitation of the stock emulsion is necessary before use.

Uses of the Emulsion.

The value of the wash as a substitute for winter washes on apples has been described above. The wash may be applied to apples at any stage from just after bud burst, using Worcester Pearmain as a guide for bud development, up to the pink bud stage. It may be used in combination with lime sulphur. It provides a complete control of Leaf Curling and Mealy Plum aphides when applied up to the white bud stage and is also satisfactory on pears when applied at the green cluster stage, and on peaches and gooseberries when applied at bud burst. The results on currants have been inconsistent : generally the control of aphides is satisfactory but in some seasons the buds open well before the date of egg hatch and under these circumstances the aphides enter deep

*It should be noted that solution of the succinate in the solvent results in an increase in volume. If 20 lb. succinate are dissolved in 20 pints of acetone (= 4 oz. in 5 fluid oz.) the final volume will be about 32 pints (=4 oz. in 8 fluid oz.). This solution is therefore used at the rate of 8 fluid oz. per 100 gallons dilute wash.

into the bud beyond the range of action of the wash. For this reason application at the tight cluster stage is preferable and may be made in conjunction with lime sulphur for the control of big bud mite. The combined wash, in addition, gives a substantial control of Leaf Curling Midge. It should be noted that in spite of the low concentration of gamma BHC there is uncertainty concerning the liability to taint the ultimate fruit crop.

The application of a combined wash of DDT and gamma BHC, although of low concentrations, is accompanied by the risk of increasing liability to Red Spider attack. It is therefore necessary to give additional attention to the control of this mite.

SPRAY APPLICATION PROBLEMS: XII. FURTHER FIELD EXPERIMENTS ON THE CONTROL OF APPLE SCAB BY SMALL-VOLUME SPRAYS.

By H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN.

Experiments at Long Ashton in 1952 (Kearns, Marsh and Morgan, 1953) indicated that large-volume applications of lime sulphur by hand-lance gave the highest level of scab control but that automatic air-flow applications at 100–200 gal. per acre using 1% and 2% lime sulphur gave satisfactory commercial control in that season. In one trial in 1952 three air-flow applications of 4% lime sulphur caused crop reduction on Worcester Pearmain.

For the 1953 season it was decided that all air-flow applications should be carried out using lime sulphur at not more than 1% concentration with a wetter* and at approximately 100 gallons per acre per application, in comparison with lance-applied lime sulphur sprays at the same concentration and times but at approximately five times the volume per acre.

Plots and treatments.

The Worcester Pearmain trees in Plot 23 (Fig. 1) were those used in the previous year's trials and described in the 1952 report. A second trial was made on the Cox's Orange Pippin trees in Plot 14, also described in the 1952 paper, and on the inter-planted Worcesters of the same age (see Fig. 2).

The machines and methods of application were as recorded for the 1952 trials, with the addition on the airflow mist blower of the "fish-tail" fan trunking described on page 139 of this report.

The lay-out of the experiments, being limited by the difficulties of spray drift, followed the previous year's pattern of placing the blocks for small-volume treatment on the leeward side of the plots. In Plot 23, 80-tree blocks were used for each of the three treatments: small-volume, large-volume and control. On Plot 14, 57 trees were used for small-volume spraying, 67 for large-volume, and there was a small control block of 15 trees. (See Figs. 1 and 2).

The complete fungicide spraying programme is set out in Table I. It will be noted that on Plot 14 the full comparisons of spraying treatments were made for only three out of the five applications.

Weather.

The 1953 season was exceptionally favourable for scab and unfavourable for spraying. In May and early June high winds and frequent rainstorms seriously interfered with spraying operations and made satisfactory application of the small-volume sprays unusually difficult. The rainfall (in inches) for the summer months was: May 1·91, June 2·15, July 4·12, August 5·36, September 3·48. In the 140 days from mid-May to the end of September, measurable rain was recorded on 68 days and a trace of rain on 27 more.

* 3 oz. (100%) dioctyl sodium sulphosuccinate per 100 gal. wash.

TABLE I.

RECORDS OF SPRAY TREATMENTS.

(A) Plot 23 (Worcesters).

Method of spraying and number of trees	Spray applications and quantities per acre			
	Pink stage 30 April–5 May	Petal-fall 18–23 May	Fruitlet 28 May	Mid-June 13 June
Large volume : Lance (80 trees)	1% l.s. (800 gal.)	1% l.s. (950 gal.)	—*	¾% l.s. (600 gal.)
Small volume : Air-flow (80 trees)	1% l.s. (130 gal.)	1% l.s. (130 gal.)	¾% l.s. (160 gal.)	¾% l.s. (130 gal.)
No spray (80 trees)	—	—	—	—

*This application omitted in error.

(B) Plot 14 (Worcester, Cox, etc.).

Meathod of spraying and number of trees	Spray applications and quantities per acre				
	Pink stage 4 May	Petal-fall 20 May	Fruitlet 28 May	Mid-June 15 June	Early-July 7 July
Large volume : Lance (67 trees)	1% l.s. (480 gal.)	1% l.s. (500 gal.)	¾% l.s. (600 gal.)	¾% l.s. (540 gal.)	¾% l.s. (560 gal.)
Small volume : Air-flow (57 trees)	1% l.s. (130 gal.)	1% l.s. (72 gal.)	¾% l.s. (120 gal.)	¾% l.s. (110 gal.)	¾% l.s. (480 gal.)*
Control (15 trees)	1% l.s. (500 gal.)*	—	—	—	¾% l.s. (530 gal.)*

*Lance applications.

Method of Recording.

On Plot 14, records were made on all the Cox and Worcester trees in the control block and on 10 Cox and 10 Worcester trees on each of the other blocks. On Plot 23, records were made on 16 trees in each block. For each tree, mean percentage scabbed areas per leaf and per fruit were computed from samples of 250 leaves and 100 fruits respectively. The overall means per block are shown in Table II. Finally the crops were harvested, weighed and commercially graded for scab. The fruit was graded into two groups : (a) practically free from scab ; and (b) obviously infected. The results are expressed as average weights per tree and percentage of scabbed fruit.

These results indicate the high level of scab attack at Long Ashton in 1953. In spite of this, complete control was obtained by a programme of five applications of large-volume lime sulphur sprays (two at 1% plus three at ¾%) on the Cox and Worcester trees in Plot 14. On Plot 23, despite the omission of a petal-fall application, a programme of three large-volume sprays

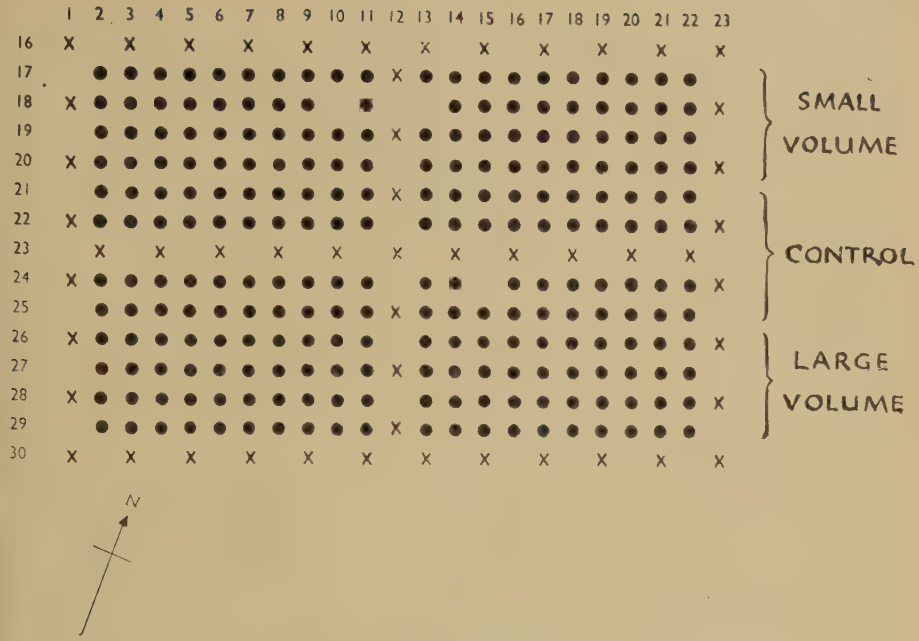


Fig. 1. Lay-out of trial on Plot 23.

Fig 2

LAY-OUT OF TRIAL ON PLOT 14.

W = Worcester.
C = Cox, x = other varieties.

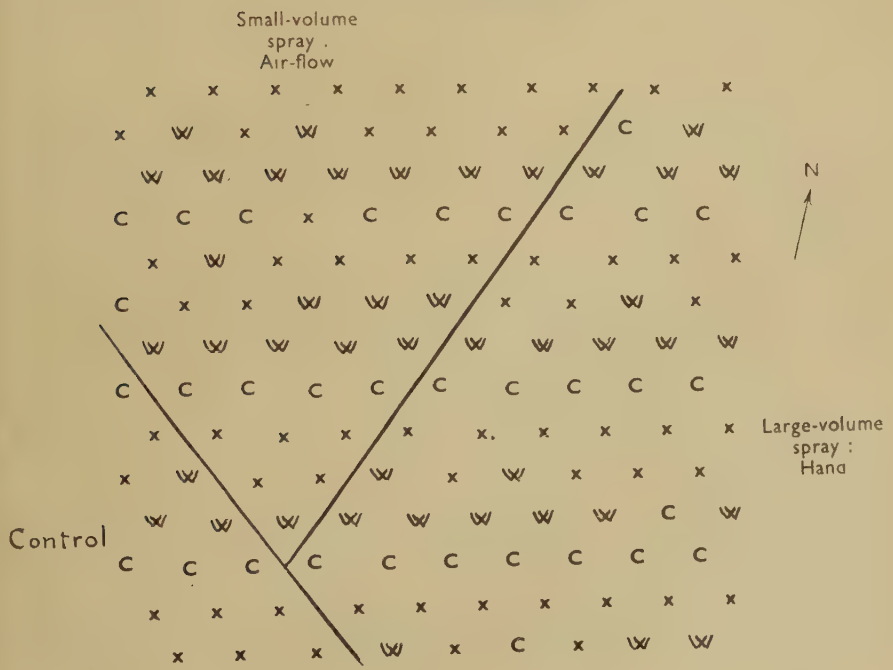


TABLE II.

RESULTS OF TREATMENTS.

(A) Plot 23 (Worcester Pearmain).

Method of spraying	Mean % scabbed area		Graded fruit	
	Leaves (23 July)	Fruits (13 Aug.)	Weight (lb. per tree)	Scabbed (% by weight)
Large volume : Lance ..	0·04	0·24	58·7	21·5*
Small volume : Air-flow ..	1·05	0·84	41·4	67·0
No spray	1·57	2·11	9·3	96·4

*"10 days after petal-fall" application omitted (see Table I).

(B) Plot 14 (Worcester Pearmain and Cox's Orange Pippin).

Method of spraying	Mean % scabbed area		Graded fruit			
	Leaves		Weight (lb. per tree)		Scabbed (% by weight)	
	Worcs.	Cox	Worcs.	Cox	Worcs.	Cox
Large volume : Lance ..	0·005	0	67·1	70	0	0
*Small volume : Air-flow ..	0·38	1·56	77·6	33·7	28	69·8
*Control	1·37	2·51	6·9	10·0	78·2	93·4

*See note to Table I (B).

reduced the percentage by weight of scabbed fruit to a quarter of the amount on the unsprayed trees. These results demonstrate the value of lime sulphur sprays applied at 500–800 gal. per acre at no higher concentration than 1% throughout the season.

With the small-volume sprays, the percentage by weight of scabbed fruit on Plot 23 (Worcesters) was reduced only to two-thirds of that on the controls and on the Worcesters on Plot 14 to one-third. The poorest result was on the Cox trees and this is probably related to the fact that the records were not taken until 1st September by which time infection had been accentuated by the wet weather of early August.

In both plots, the lay-outs were substantially the same as in 1952, so the differences in 1953 represent the cumulative effects of treatments continued for two seasons in succession.

In comparing the results obtained in these experiments with those of other trials using small-volume sprays it must be borne in mind that the opportunity of using concentrated fungicides was deliberately relinquished in the 1953 trials. The comparisons have been made throughout between large-volume and small-volume lime-sulphur sprays *both at not more than* 1% *strength*. These 1953 results have shown that on conventionally-spaced bush apple trees

in a wet season small-volume spraying gives poorer scab control than high-volume spraying when the strengths of lime sulphur and the number of applications are the same for both treatments. Further trials will explore the merits of small-volume spraying for apple scab control when the number of applications and/or the concentrations of the fungicide are increased.

Summary.

In a season favouring apple scab attack, large-volume spraying applied by lances (>500 gal. per acre), using lime sulphur at not more than 1% with a wetter, gave excellent control of the disease.

Air-flow small-volume spraying, at 100–150 gal. per acre, using the same concentrations of lime sulphur at the same times as for the large-volume applications, gave an unsatisfactory control of scab.

Acknowledgments.

The spraying treatments were carried out by Messrs. C. H. Harper and J. H. Russell and some of the recording was done by Mr. P. D. Turner whose help is gratefully acknowledged.

REFERENCE.

Kearns, H. G. H., Marsh, R. W. and Morgan, N. G. (1953). Spray application problems : IV. Preliminary field experiments on the control of apple scab by small-volume sprays. *Ann. Rep. Long Ashton Res. Sta.*, 1952, 90-95.

BLACKCURRANT LEAF SPOT: I. STUDIES OF PERENNATION AND INFECTION.

By A. T. K. CORKE.

As the life-cycle of *Pseudopeziza ribis* Kleb., the fungus causing blackcurrant leaf spot, is incompletely known an investigation into its life-history on the blackcurrant variety Baldwin was begun early in 1953.

The principal objects of the study were to establish the method of perennation of the fungus with a view to combating the disease during the dormant period, and to ascertain the time and the conditions under which the primary and secondary infections occur.

Observations on perennation and infection.

Perennation.

Preliminary experiments showed that ascocarps of the fungus were readily produced on dead blackcurrant leaves collected from early January onwards and subjected to incubation in a damp chamber at about 21°C. The period required for maturation of the ascospores under these conditions diminished as the time of natural discharge approached. Records of the discharge and germination of ascospores in the laboratory showed that although apparently mature ascospores were formed in January, actual discharge from incubated leaves began at the end of March and germination started late in April.

The occurrence of the perfect stage of *P. ribis* in the blackcurrant plantation at Long Ashton was finally confirmed by immediate discharge from leaves collected at the end of May.

Since there appeared to be no infection of newly-formed blackcurrant leaves in the field in late April, the viability of ascospores was tested in the laboratory at this time by subjecting leaves of potted blackcurrant bushes to the natural discharge of ascospores from leaf fragments held up to four millimetres away. Infection took place and typical symptoms became visible after 9 days, followed by the formation of viable conidia.

Secondary infection.

The appearance of leaf spot on blackcurrants of the variety Baldwin in the field was first noticed in 1953 at the end of May on the leaves surrounding the fruit clusters, and in early June on the lower foliage. The disease tended to spread distally along the leaves of a shoot and reached the youngest leaves of the bushes late in August when most of the lower leaves had already been killed. It was found that healthy leaves adjacent to infected leaves themselves became infected and killed within 6 weeks during the period July-August.

Defoliation in the field was almost complete by mid-September.

Laboratory experiments on infection.

Inoculations of leaves in the laboratory with ascospores and conidia showed that the resulting lesions grew very slowly. Five-month-old lesions on leaves of blackcurrant bushes kept under laboratory conditions averaged 8-10

square millimetres. It was only where lesions were sufficiently close to become fused, thereby surrounding an area of the leaf which suffered gradual degeneration, that serious damage occurred.

Such damage in the field was found to result from infections following summer rainstorms, since the first appearance of the subsequent lesions showed their limits to be almost contiguous over large areas of the leaves.

Inoculations of both surfaces of leaves with ascospores and conidia were found to be successful only on the lower surface, although the resultant infections penetrated through the leaf and formed conidia on both surfaces. The splashing of raindrops carrying conidia from the upper surfaces of infected leaves to the lower surfaces of healthy leaves, where conditions most suitable for infection prevail, is suggested as an explanation of the upward progress of the disease mentioned above.

Field experiments on infection.

A square plot of 230 blackcurrant bushes of the variety Baldwin, at the south-western corner of a plantation at Long Ashton, was chosen for field experiments. Three treatments carried out on this plot were arranged to provide information on the nature of infection, and on possible lines of future work on the control of this disease.

Methods. The treatments were as follows :—

Raking. Dead leaves and fragments were removed from half the bushes, and the surrounding ground was raked on 12th February, 1953.

Spraying (*a*). A 0·1% solution of dinitro-*ortho*-cresol in 2% oil emulsion was used as a ground spray on half the plot on 25th February, 1953. The spray was applied with a twin-nozzle hand lance at a pressure of 75 lb. per square inch at a rate of 650 gallons per acre.

(*b*). 1½% lime sulphur was applied on part of the plot on 8th April, 1953.

In order to prevent disturbing the surface of the soil during the period of the experiment a heavy mulch of partly-composted straw was applied to the whole plot in mid-February.

The above treatments were arranged to include all possible combinations, and periodical assessments were made of the amount of leaf spot on bushes selected at random. The first assessment was made on 3rd June, soon after the appearance of leaf spot in the experimental plot. On this occasion the total number of infected leaves was counted, this figure being expressed as a percentage of the total number of leaves per bush, an arbitrary figure of one thousand being taken for this purpose. On 29th June and 21st July counts were made of the numbers of infected and uninfected leaves on five shoots on each bush (see Table I).

The outermost treated row on each side of the experimental plot was omitted from the above assessments. Cropping took place after 16th July.

Results.

Statistical analysis of the results given in Table I showed that each of the three treatments had a significant overall effect on the incidence of leaf spot, an effect which persisted beyond the cropping date. The analysis also showed that although raking was consistently the best single treatment, no

TABLE I.

TREATMENT	PERCENTAGE INFECTION					
	3rd June	Mean	29th June	Mean	21st July	Mean
Control	16·05	16·05	61·00	61·00	94·91	94·91
LS	6·25		50·74		94·91	
DNC	6·20	4·90	45·67	43·58	97·75	94·54
Raking	2·25		34·33		90·96	
DNC + LS ..	1·35		19·86		89·93	
Raking + LS ..	0·95	1·07	24·07	23·91	86·91	87·35
Raking + DNC ..	0·90		27·81		85·21	
Raking + DNC .. + LS ..	0	0	10·99	10·99	52·01	52·01

LS = Lime Sulphur. DNC = Dinitro-*ortho*-cresol.

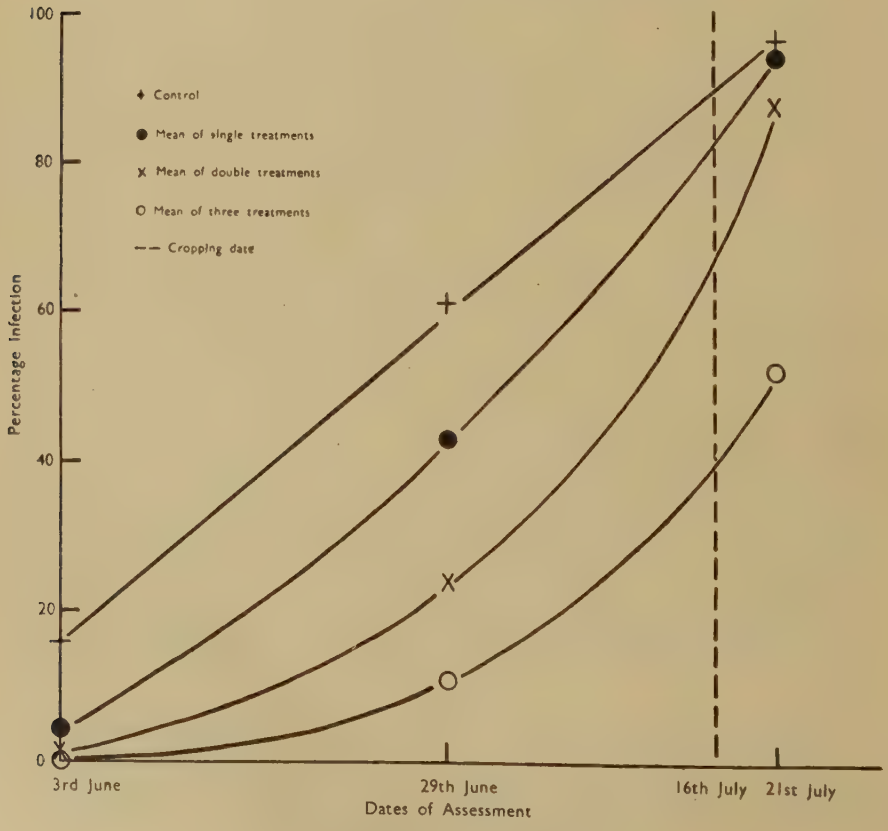


Fig. 1. Comparison of Treatments.

one treatment or pair of treatments was significantly better than another. A combination of all three treatments, however, had a significant effect which lasted throughout the fruiting season (see Fig. 1).

Discussion.

Although it is known that the overwintering perfect stage of *Pseudopeziza ribis* on fallen blackcurrant leaves provides a natural source of inoculum each spring, this stage has seldom been reported. In consequence, alternative methods for the perennation of the fungus have been examined by previous workers.

It has been shown that conidia formed on dead leaves during the spring can cause infections, and also that autumn conidia exposed to normal winter weather conditions in the United States and Europe are able to germinate in the following spring, but these have not been shown to cause infections (1, 2).

Observations at Long Ashton suggest that the perfect stage may occur more generally than has hitherto been supposed, and since the ascospores mature at lower temperatures than the conidia, and are able to infect very young leaves (1), the period and frequency of primary infections would be considerably increased if both types of spore were present in the spring. The part played by secondary infections in bringing about the rapid death of the leaves and premature defoliation in the late summer has been mentioned above.

The appearance of the lesions only on the non-woody parts of the host suggests that no other means of overwintering normally occurs. This is borne out by the experiment described above in which the removal of dead leaves was shown to delay significantly the onset of leaf spot in early summer, an effect probably attributable to the removal of most of the inoculum with the leaves.

A similar effect was also noticeable, but to a lesser degree, on the bushes treated with a ground spray in February or lime sulphur in April. The former result was comparable to that obtained by raking, and was again probably due to the inactivation of most of the inoculum. It is possible that the present tendency to reduce the spring spraying of blackcurrants with lime sulphur may remove a check to early infection by *Pseudopeziza*.

The results of these experiments have at most a limited value in that the plot available was too small to allow replication of treatments, and complete statistical analysis was therefore not possible. It nevertheless appears that the application of a suitable ground fungicide to the overwintering leaves during the dormant period may delay the onset of leaf spot for a considerable time, even if more complete control is not possible by this means. The greater the delay achieved, the less will be the damage done to leaves and fruit before cropping, and the later will defoliation begin.

Control experiments based on this principle, together with further experiments on perennation and infection, are in hand.

Summary.

The presence of the perfect stage of *Pseudopeziza ribis* Kleb. on the dead leaves of blackcurrant bushes at Long Ashton was confirmed during the winter of 1952-53.

Laboratory infections with ascospores and conidia showed that individual lesions had a very limited effect on the leaves. The damage done in the field was attributed to the mass infections that occurred following summer rainstorms.

Primary infections in the field were observed mainly in May on the leaves surrounding the fruit clusters.

The removal in February of the dead leaves from the ground around the bushes was found to reduce the incidence of leaf spot significantly, an effect which persisted throughout the summer. This result was obtained to a smaller degree by the application of 0·1% dinitro-*ortho*-cresol as a ground spray during the dormant period, and also by the routine application of 1½% lime sulphur in early April near the time of primary infection.

Acknowledgments.

The author wishes to thank Miss M. Marlow for her assistance in the assessment of the experimental results, and Mrs. P. M. Fowles for the statistical analysis.

REFERENCES.

(1) Blodgett, E. C. (1936). The anthracnose of currant and gooseberry caused by *Pseudopeziza ribis*. *Phytopathology*, **26**, 115.

(2) Ewert, R. (1910). Die Überwinterung von Sommerkonidien pathogener Ascomyceten und die Widerstandsfähigkeit derselben gegen Kälte. *Zeitschr. Pflanzenkr.*, **20**, 129.

THE ROLE OF ERADICANT FUNGICIDES IN THE CONTROL OF APPLE CANKER. II.

By R. J. W. BYRDE and A. T. K. CORKE.

An earlier paper summarised the results of experiments on the possible control of apple canker (caused by *Nectria galligena* Bres.) by means of eradicant fungicides (Byrde, Crowdy and Roach, 1952). It was shown that 0·3% phenyl mercury chloride, applied in late autumn or winter, reduced the sporulation of established cankers, thereby effecting a control of subsequent leaf scar infections. A more recent note (Taylor and Byrde, 1954) described the effect of such a treatment on the fruit eye-rot stage of the fungus. The present paper gives a more detailed study of cankers on trees receiving sprays of phenyl mercury chloride and other eradicant fungicides during the winter months.

Materials.

Trees.

The experiments were carried out on thirty-two bush apple trees of the variety Worcester Pearmain planted as guard rows in a large block of Cox's Orange Pippin. The trees, set out in 1935, stood at 21 ft. apart in grass.

Fungicides and dates of application.

The spray materials were formulated as follows :—

Phenyl mercury chloride, as a 0·3% suspension in 0·3% sulphite lye, applied in November 1951, and again in October 1952.

Sodium pentachlorophenate, as an aqueous solution used at 0·5% in November 1951, and at 1% in October 1952.

Pentachlorophenol, in a tar-oil emulsion containing 0·7% pentachlorophenol and 3·5% tar oil, applied in February 1952. Sprays were applied by means of a conventional large-volume outfit.

Estimation of Results.

Viability and sporulation of the fungus.

To study the effect of the treatments on the fungus, random samples of four cankers per treatment were examined in the laboratory at intervals of approximately two months, starting in November 1952. The cankers were immersed in distilled water in separate boiling tubes ; after eighteen hours the tubes were shaken vigorously and the water poured off and retained.

The cankers were then surface-sterilised by shaking for 30 seconds in a 0·1% solution of mercuric chloride in 70% alcohol, and washed in three changes of distilled water before being placed on pads of damp cotton wool in sterile tubes. After two months at room temperature the development of mycelium or perithecia of *N. galligena* was recorded.

The water in which the cankers were washed was passed through a lens tissue, to remove coarse fragments, and then centrifuged for five minutes at 2,500 r.p.m. After decanting, the deposit was made up to 2 ml. with 1% sucrose, and haemocytometer counts were made of the spore concentration

TABLE I.

VIABILITY AND SPORULATION OF *N. galligena* IN TREATED CANKERS.

Date collected	Treatment **	Spore concn. ($\times 10^3$)		Percent. germn. (same concn.)		Date of lab. exam.	Cankers showing mycelial growth	Cankers showing perithecia
		Conidia	Ascospores	Conidia	Ascospores			
12/11/52 ..	Control	125	0	89·1	—	5/ 1/53	4	2
	Pcp.	173	0	90·0	—		3	3
	PMC	38	0	57·2	—		2	0
16/ 1/53 ..	Control	212	0	81·6	—	17/ 3/53	3	0
	Pcp.	346	0	95·7	—		2	1
	NaP.	88	0	56·3	—		2	2
	PMC	12	0	*	—		0	1ø
31/ 3/53 ..	Control	58	46	88·0	97·0	27/ 5/53	3	1
	Pcp.	332	2	94·0	*		2	2
	NaP.	30	0	80·0	—		4	0
	PMC	0	0	—	—		2	0
16/ 6/53 ..	Control	1,136	0	98·3	—	19/ 8/53	3	2
	Pcp.	152	0	96·3	—		4	2
	NaP.	570	0	97·0	—		3	3
	PMC	196	0	99·7	—		3	0
20/ 8/53 ..	Control	2,060	0	58·0	—	27/10/53	3	0
	Pcp.	392	0	58·2	—		4	0
	NaP.	2,024	0	81·2	—		3	0
	PMC	992	0	66·0	—		2	0
26/10/53 ..	Control	284	0	88·1	—	19/12/53	3	0
	Pcp.	1,002	0	83·4	—		3	0
	PMC	354	0	77·4	—		1	0
30/12/53 ..	Control	180	0	98·0	—	5/ 3/54	4	4
	Pcp.	310	0	96·5	—		3	3
	PMC	230	0	96·5	—		3	0

øBlackened and dead.

*Insufficient for spore germination tests.

**Pcp. = Pentachlorophenol 0·7%, Feb. 1952.
NaP. = Sodium pentachlorophenate 0·5%, Nov. 1951, and 1%, Oct. 1952.
PMC = Phenyl mercury chloride 0·3%, Nov. 1951, and Oct. 1952.

obtained from the four cankers in each treatment. The suspensions were then diluted with the 1% sucrose solution to the level of the lowest spore concentration. Sample drops were pipetted out on slides and counts made of the germination of the spores after 18 hr. at 25°C.

Leaf scar infections.

The incidence of leaf scar infections was estimated on the basis of the number of infections per 100 shoots per treatment (1952), or as the number per 100 leaf scars per tree (1953).

Spread of established cankers.

The spread of treated and untreated cankers was studied by tracing their outline on a celluloid sheet, and computing the area infected by means of a planimeter. This was done on two dates, and the increase in area during the intervening period calculated as a percentage.

Results.

Viability and sporulation of the fungus.

Table I summarises the results of laboratory examinations carried out at two-monthly intervals.

The two applications of phenyl mercury chloride (November 1951, and October 1952), alone of the three spray treatments, resulted in the reduction of sporulation and spore viability, and of the activity of the fungus within the tissues until the end of March 1953. No fresh perithecia have been produced on treated cankers since the applications of this fungicide.

Leaf scar infections.

The incidence of leaf scar infections in 1952 and 1953, recorded on June 12th and June 11th respectively, is shown in Table II.

TABLE II.

THE INCIDENCE OF LEAF SCAR INFECTIONS OF APPLE CANKER FOLLOWING FUNGICIDAL TREATMENT.

Treatment	Date of application	No. cankers per 100 shoots 1952	Mean % leaf scars infected 1953
Phenyl mercury chloride 0·3% ..	Nov. 1951 Oct. 1952	44	3·9
Sodium pentachlorophenate 0·5% ..	Nov. 1951	49	6·7
„ „ 1% ..	Oct. 1952		
Pentachlorophenol 0·7% ..	Feb. 1952	56	7·1
Control	—	63	6·6

The results with phenyl mercury chloride are similar to those obtained in earlier trials (Byrde *et al.*, 1952). The other two treatments appear less effective.

Spread of established cankers.

The percentage increase in area of established cankers selected at random from each of three treatments was estimated over the period May 6th–August 4th. 1953. Table III summarises the results obtained.

Clearly. neither fungicide checked the spread of established cankers during the summer following treatment.

TABLE III.

EFFECT OF FUNGICIDE TREATMENTS ON SUBSEQUENT GROWTH OF ESTABLISHED CANKERS.

Treatment	Mean increase in area (%)
Phenyl mercury chloride	90
Sodium pentachlorophenate	104
Control	71

Discussion.

The experiments carried out confirmed the view previously expressed (Byrde *et al.*. 1952), that the application of 0·3% phenyl mercury chloride in late autumn suppresses the sporulation of *N. galligena* for a considerable period, and that this in turn appears to lead to a reduction in leaf scar infection. This treatment, however, did not arrest the subsequent growth of established cankers. a serious drawback to the use of this costly fungicide.

It is therefore suggested that this treatment used as a paint in conjunction with rigorous excision, and not as a substitute for it (Byrde *et al.*, 1952), may be useful, especially on young trees, in restricting the spread of the disease from established cankers.

Summary.

Laboratory examination of cankers treated in the field with eradicant fungicides confirmed that phenyl mercury chloride (0·3%) had a prolonged effect in reducing the sporulation of *Nectria galligena*. Sodium pentachlorophenate and pentachlorophenol were less effective. The subsequent growth of established cankers was not arrested by the fungicide treatments.

Acknowledgments.

The authors wish to acknowledge the valuable help of Miss M. Marlow and Mrs. P. M. Fowles in carrying out the recordings.

REFERENCES.

Byrde, R. J. W., Crowdy, S. H. and Roach, F. A. (1952). The rôle of eradicant sprays in the control of apple canker. *Ann. Rep. Long Ashton Res. Sta. for* 1951, 134-137.

Taylor, R. E. and Byrde, R. J. W. (1954). A note on the control of *Nectria* eye-rot of apple by an eradicant fungicide. *Plant Pathology* (in the press).

OBSERVATIONS ON THE SPORULATION OF SCLEROTINIA FRUCTIGENA ON MUMMIFIED APPLES AND PLUMS IN LATE SPRING AND SUMMER.

By R. J. W. BYRDE.

The significance of mummified fruits in the overwintering of the brown rot fungus, *Sclerotinia fructigena* Aderh. and Ruhl., has long been recognised. It has been established that the fungus becomes dormant in such fruits during late autumn, but produces a fresh crop of conidia during the following spring and summer (Wormald, 1935; p. 59). Little is known, however, of the precise climatic conditions governing the renewal of sporulation in spring, although Wormald (1935, p. 14), writing of the brown rot fungi in general, states that dull weather, with frequent showers or mists, is most favourable to the production of conidia.

In the course of investigations at Long Ashton in 1951-53 on the effect of fungicidal treatments on the sporulation of mummified fruits, records were made of the dates when fresh conidial pustules were observed on untreated fruits. This note deals with the meteorological conditions at the time of such outbreaks.

Experimental.

Mummified Fruits.

Mummified apple and plum fruits, of mixed varieties, were collected during the early winter, and placed in a single layer on cellulosed wire-netting trays on a rack structure in the open. During the subsequent April, May and June, records were kept of the date and intensity of outbreaks of sporulation of *S. fructigena*. These outbreaks occurred overnight, and pustules were not seen to develop during the day. No outbreak was observed during April.

Meteorological data.

Meteorological data were abstracted from the official Long Ashton Research Station records, which were taken in accordance with the Meteorological Office Observer's Handbook (1952).

Results.

Meteorological records for April, May and June, 1951-53 are plotted in Figure 1, together with the dates of outbreaks of sporulation of *S. fructigena* on mummified fruits. The data for the twenty-four hour periods preceding such sporulation are abstracted in Table I.

Discussion.

Examination of the results presented indicates primarily that the incidence of rain within the previous 24 hours is necessary for the sporulation of *Sclerotinia fructigena* in overwintered mummified fruits. The action of the rain may be two-fold: in bringing about a saturated atmosphere (Wormald, 1935; p. 14), and also in moistening the normally desiccated tissue of the mummified fruits, thus facilitating fungal growth.

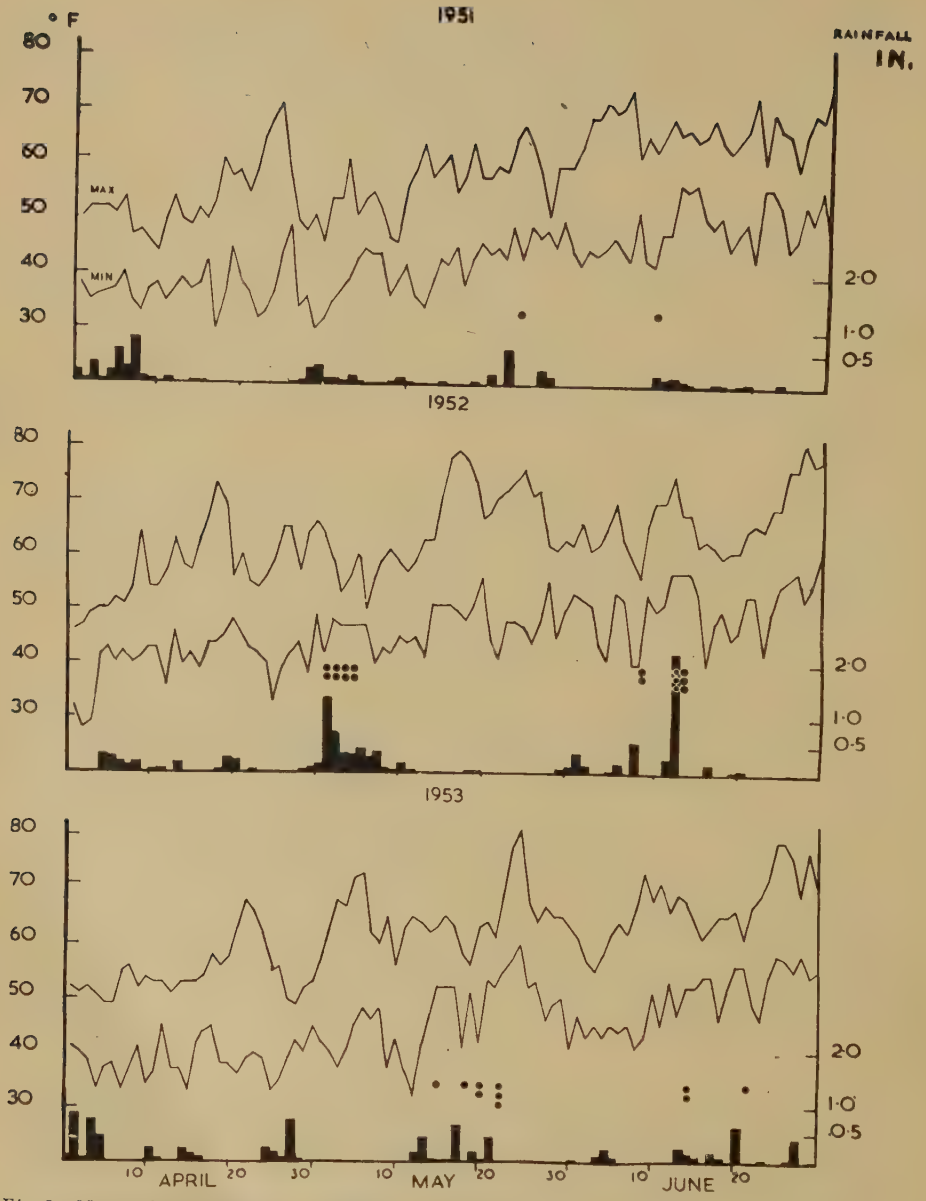


Fig. 1. Meteorological records in relation to sporulation of *S. fructigena* on mummified fruits April, May and June, 1951–53.

Key : Intensity of sporulation.

• Slight. ⋮ Moderate. ⋮ Heavy.

TABLE I.

METEOROLOGICAL DATA AT THE TIME OF OUTBREAKS OF SPORULATION OF *S. fructigena* ON MUMMIFIED FRUITS :—MAY AND JUNE, 1951–53.

Month Date & Year	Intensity of outbreak	Preceding Day		Preceding Night	Preceding 24 hr.
		Max. temp. (°F.)	Sunshine (hr.)	Min. temp. (°F.)	Rainfall (in.)
May 2 (1952)	Moderate	64	3·8	48	1·38
„ 3 (1952)	Moderate	59	0·1	47	0·73
„ 4 (1952)	Moderate	53	0·0	47	0·32
„ 5 (1952)	Moderate	56	0·0	47	0·31
„ 15 (1953)	Slight	62	2·6	52	0·43
„ 19 (1953)	Slight	58	0·0	51	0·65
„ 21 (1953)	Moderate	63	1·4	53	0·17
„ 23 (1953)	Heavy	61	1·1	55	0·43
„ 24 (1951)	Slight	65	1·0	53	0·27
Mean value		*60·1* (*61·7*)	*1·1* (*6·4*)	*50·3* (*44·3*)	*0·52* (*0·08*)
June 9 (1952)	Moderate	56	0·0	53	0·56
„ 10 (1951)	Moderate	63	2·2	48	0·18
„ 13 (1952)	Heavy	75	9·3	57	0·27
„ 14 (1952)	Heavy	68	0·2	57	2·21
„ 15 (1953)	Moderate	68	3·4	52	0·23
„ 22 (1953)	Slight	61	0·0	49	0·64
Mean value		*65·2* (*67·0*)	*2·5* (*7·09*)	*52·7* (*49·8*)	*0·68* (*0·07*)

Monthly normal values are shown in brackets.

The absence of outbreaks of sporulation following the cool nights during the month of April in each of the three years, coupled with the relatively high overnight minimum temperatures at the time of outbreaks in May and June, suggests that overnight temperature may also play a part in inducing the sporulation of mummified fruits.

Laboratory studies on the sporulation of *S. fructigena* in culture have demonstrated the significance of alternating light and darkness in the initiation of spore production (Hall, 1933). While the stimulus for sporulation was found to be effected by daylight, the actual development of aerial mycelium occurred during the subsequent period of darkness. In the field, where there is a daily light stimulus, the overnight weather conditions, rather than those of the previous day, would therefore be expected to govern the development of spore pustules.

Further experiments are being planned, to extend over a number of years, using a thermohydrograph to furnish continuous temperature and humidity data on which a full statistical analysis may be based.

Summary.

Preliminary observations were made in 1951-53 on the occurrence of outbreaks of sporulation of *Sclerotinia fructigena* on overwintered mummified apple and plum fruits in April, May and June. Examination of routine meteorological data indicates that moderate rainfall, coupled with relatively high overnight temperatures, induces such outbreaks.

Acknowledgments.

The author wishes to thank Mr. R. W. Marsh and Dr. H. E. Croxall for helpful discussion, and Mr. G. E. Clothier for access to the meteorological records.

REFERENCES.

Hall, M. P. (1933). An analysis of factors controlling the growth form of certain fungi, with especial reference to *Sclerotinia* (*Monilia*) *fructigena*. *Ann. Bot.*, **47**, 543.

Meteorological Office (Air Ministry) (1952). *Observer's Handbook*. H.M.S.O., Lond. (216 pp.).

Wormald, H. (1935). The brown rot diseases of fruit trees. *Bull. Minist. Agric., Lond.*, no. 88 (50 pp.).

SPRAYING EXPERIMENTS AGAINST APPLE AND PEAR SCAB AT LONG ASHTON, 1953.

By R. J. W. BYRDE, A. H. FIELDING and C. W. HARPER.

This report forms a continuation of work on the testing of organic fungicides against apple and pear scab (caused by *Venturia inaequalis* (Cooke) Wint. and *Venturia pirina* Aderh. respectively) at Long Ashton (Byrde and Marsh, 1951, 1952; Byrde and Fielding, 1953). In 1953, the comparison of a phthalimide spray (captan) with lime sulphur on Cox's Orange Pippin apples was continued, and records were obtained on the control of apple mildew (caused by *Podosphaera leucotricha* (Ell. and Everh.) Salm.). Captan and 2-heptadecyl glyoxalidine were again compared for scab control and phytotoxicity on the pear varieties Doyenné du Comice and Williams Bon Chrétien, and were also used as routine sprays in the main Long Ashton plantations on the apple variety Lane's Prince Albert.

Experimental.

Fungicides.

The spray materials were formulated as follows :—

Lime sulphur, as the commercial concentrate, diluted to 2% (pre-blossom) or 1% (post-blossom).

N-Trichloromethylthio-tetrahydrophthalimide (formerly SR.406, now designated " captan "), as a 50% wettable powder used at 2 lb. per 100 gal.

2-*Heptadecyl glyoxalidine*, as a water-miscible liquid containing 34% active material, used at 3 pints per 100 gal. with 8 oz. hydrated lime added to the dilute spray.

The materials were applied by a mobile spraying machine using 2 triple-nozzle brooms with 4/64th in. disc apertures, a short-range swirl plate in the centre and two long-range swirl plates on the outside. The output of each broom was 7 gallons per minute.

Notes on Weather.

The total rainfall of the summer months of 1953 was above average, as in the three previous years. The rainfall figures (in.) for each month are shown below, with the normal values (1914–48) in brackets :—April, 4·07 (2·25); May, 1·91 (2·52); June, 2·15 (2·14); July, 4·12 (3·26); August, 5·36 (3·41); September, 3·48 (3·07); Total, 21·09 (16·65); Excess over normal, 27%.

As might be expected in so wet a summer, a severe outbreak of apple scab developed. Its control on the developing fruits was rendered particularly difficult by very unsettled weather at the petal-fall period : the total rainfall for May (1·91 in.) occurred during the ten-day period May 13th–22nd, in which measureable rain fell on nine days. There was again heavy wood infection on untreated trees of the variety Cox's Orange Pippin, followed by severe defoliation and fruit drop.

Methods of Assessment.

Mean percentage scab areas per leaf and per fruit were again estimated by Tehon and Stout's method, as amplified by Marsh (1947), based on samples

of 250 leaves and 50 fruits. Fruit scab on pears was assessed by comparison with standard models (Croxall, Jenkins, Byrde and Marsh, 1953).

Apple mildew incidence was estimated by an examination of ten shoots of the current season's growth on each tree, recording each as infected or healthy.

Fruit crop was recorded as the number of bushel boxes per tree ; for pears, the number of fruits per tree was counted.

Phthalimide trial : Cox's Orange Pippin.

This trial was first laid out in 1952 on a block of 60 Cox's Orange Pippin bush apples, with guard rows of Worcester Pearmain. Captan 50% wettable powder (2 lb. per 100 gal.) and lime sulphur (2% pre-blossom, 1% post-blossom) were compared in two randomised blocks, with Control trees included.

In 1953, sprays were applied on April 22nd, May 25th and June 19th. The petal-fall application (May 25th), which was delayed for some days by bad weather, incorporated nicotine (8 fl. oz. per 100 gal.) and wetting agent (sodium dioctyl sulphosuccinate, 4 oz. per 100 gal.) to control apple sawfly. The Control trees received the insecticide spray only.

The use of only three applications in a season very favourable to apple scab provided a severe test for the fungicide sprays.

Leaf scab was estimated on August 1st–7th, fruit scab and crop weight on September 24th–28th, and the incidence of apple mildew on August 14th. Table I summarises the results obtained.

TABLE I.

COMPARISON OF CAPTAN AND LIME SULPHUR ON COX'S ORANGE PIPPIN APPLES : 1953.

Fungicide	Mean % leaf scab	Mean % fruit scab	Mean % young shoots mildewed	Mean crop per tree (bushels)
Captan	0·15	0·91	59	2·8
Lime sulphur	0·19	1·99	16	0·5
Control	0·39	5·10	48	0·2†
Least sig. diff. .. .. ($P = 0·05$)	0·05	0·64	ø	1·1

† owing to very heavy scab infection.
ø differences not significant.

Used only three times in the season, with a gap of thirty-three days between the first and second application, lime sulphur afforded a relatively poor control of apple scab. It is probable that the heavy scab infection, rather than normal sulphur injury, led to the considerable fruit drop reflected in the crop figure for lime sulphur. Captan, applied on the same dates, gave a significantly better control of fruit scab and ensured a satisfactory crop. The data on apple mildew, while too variable for the establishment of statistically significant differences, suggest that captan may have little effect on the disease.

The premature defoliation of the control trees in 1953 was followed by a delay of a few days in their blossoming in 1954.

Phthalimide and glyoxalidine : Lane's Prince Albert.

The value of these organic fungicides in controlling apple scab on a sulphur-sensitive variety was well demonstrated in the main Long Ashton plantations in 1953, when two plantings of Lane's Prince Albert trees set a heavy crop of fruitlets. Standard lime sulphur sprays had been applied before blossoming, but their continued use would clearly have led to considerable crop loss. Instead, each of the organic fungicides, at the strengths stated above, was applied to half the trees on May 20th-21st, June 15th and July 15th. Nicotine and wetting agent were incorporated with the sprays on May 20th–21st, and rotenone resin and wetting agent on June 15th for the control of apple sawfly and red spider respectively. No Control trees were included in the layout and there was no attempt at randomisation.

Estimates of fruit scab were made on September 9th, with the following result : Captan, 0·03% scab ; Glyoxalidine, 0·08% scab. These figures represent a very good commercial control of scab ; a heavy crop of fruit was obtained.

Pear scab trial.

This was the third and final year of a trial of captan and glyoxalidine against pear scab on the varieties Williams Bon Chrétien and Doyenné du Comice. These two treatments, and Control, were again randomised in four blocks. Sprays were applied on April 21st, May 18th, June 13th and July 11th, using the materials at the same strengths as for the apples.

Estimates of fruit scab on Williams were made on September 1st, with the results shown in Table II, which also lists the mean number of fruits per tree on Doyenné du Comice. No statistical analysis of the data was possible, owing to the small and variable crop.

TABLE II.

PEAR SCAB TRIAL : FRUIT SCAB (WILLIAMS) AND MEAN CROP NUMBER (COMICE).

Treatment	Mean % fruit scab (Williams)	Mean No. fruits per tree (Comice)
Captan	0·31	30·9
Glyoxalidine ..	1·10	12·3
Control	4·52	13·1

Discussion.

The 1953 results confirm the promise already shown by both captan and glyoxalidine, used as high-volume sprays, at East Malling and Long Ashton. At the concentrations tested, their fungicidal performance against apple scab has been at least the equal of the standard lime sulphur sprays, while they have shown little or no phytotoxicity towards sulphur-sensitive varieties. On the other hand, it has been shown that glyoxalidine is not promising against apple mildew (Moore and Kirby, 1952 ; Byrde and Fielding, 1953) and the

data presented in this paper suggest that captan, too, may have little or no effect in checking this disease, thus supporting preliminary reports from East Malling (Moore and Kirby, 1952).

These considerations, coupled with the poor acaricidal value of captan and glyoxalidine, and their relatively high cost, suggest that their future use on apples may be restricted, in general, to post-blossom application on sulphur-sensitive varieties, particularly when a good crop has been set.

Acknowledgments.

The authors wish to thank Mr. R. W. Marsh for his continued interest and advice. They are also indebted to Mrs. P. M. Fowles, Miss M. Marlow, Miss R. Milnes-Walker and Mr. P. Turner, who assisted in the recordings.

Summary.

Captan (N-trichloromethylthio-tetrahydrophthalimide) (0·1%) gave a significantly better control of apple scab (caused by *Venturia inaequalis*) on fruits of Cox's Orange Pippin than a standard lime sulphur programme, and gave a significantly greater crop. There was some indication, however, that the material may have little or no effect on apple mildew (caused by *Podosphaera leucotricha*).

Captan (0·1%) and 2-heptadecyl glyoxalidine (0·125%) were compared for scab control and phytotoxicity on the apple var. Lane's Prince Albert, and the pears Williams Bon Chrétien and Doyenné du Comice.

Both fungicides appear suitable as post-blossom scab sprays on sulphur-sensitive varieties of apples and pears.

REFERENCES.

Byrde, R. J. W. and Fielding, A. H. (1953). Spraying experiments against apple and pear scab at Long Ashton, 1952. *Ann. Rep. Long Ashton Res. Sta.*, 1952, 103-109.

—— and Marsh, R. W. (1951). Apple and pear scab spraying experiments at Long Ashton, 1949 and 1950. *Ann. Rep. Long Ashton Res. Sta.*, 1950, 125-131.

—— —— —— (1952). Spraying experiments against apple and pear scab at Long Ashton, 1951. *Ann. Rep. Long Ashton Res. Sta.*, 1951, 122-128.

Croxall, H. E., Jenkins, J. E. E., Byrde, R. J. W. and Marsh, R. W. (1953). Spraying experiments against apple and pear scab at Long Ashton and in the West Midlands, season 1951. *J. hort. Sci.*, **8,** 196-206.

Marsh, R. W. (1947). Fruit spraying trials with certain recently-introduced fungicides. *J. Pomol.*, **23,** 185-205.

Moore, M. H. and Kirby, A. H. M. (1952). Can the new organic fungicides help the fruit-grower? *Rep. East Malling Res. Sta. for* 1951, 200-204.

PROBLEMS OF MICROBIOLOGICAL CONTROL IN CIDER-MAKING.

By F. W. BEECH and A. POLLARD.

Introduction.

Cider-making methods in England are still largely empirical and, in particular, fermentation of the juice continues to be carried out by the natural mixed flora. While the acidity of the juice gives some protection against the growth of undesirable organisms, in present practice the main safeguard against disorders is the exclusion of air. In the Continental cider- and wine-industries precautions are taken to prevent disorders, to promote the activity of desirable fermenting yeasts or to use selected yeasts (1, 2). Although the last method may not be applicable in English cider-making, the strict control of fermentation processes is essential in cider factories. Some measure of biological control would also help the small maker to avoid most of the disorders that affect his cider from time to time.

It has therefore been thought advisable to outline the methods of biological control that are applicable at various stages of cider-making ; details may be obtained from the works of reference listed at the end of the paper. Whilst it may not be possible for manufacturers to give immediate effect to all the measures recommended, they should be adopted as far as possible whenever a factory is expanded or modernised.

Fruit Supplies and Storage.

In planning fruit supplies, varieties should be chosen so that the final bulked juice will have an acidity of at least 0·45%, since juices of lower acidity are subject to bacterial disorders. Varieties naturally high in nitrogen or fruit from heavily manured orchards should be avoided as their juices ferment violently and induce unwanted hazes during storage and in cask. Windfalls and early maturing varieties should likewise be avoided : they give poor quality ciders and are often subject to disorders.

Since rotten fruit is heavily infected with moulds, film yeasts and acetic bacteria, farmers should be encouraged to deliver their fruit to the factory in good condition : if necessary an incentive bonus scheme could be instituted. Hygienic conditions of storage at the factory are also essential. In this respect the English cider-making industry falls behind its Continental counterpart. Sacks should not be used. The best method of storage is undoubtedly shallow layers of apples in silos under open-sided sheds. Water running in channels underneath the silos is the ideal system for transporting the fruit to the elevator and mill : it avoids bruising and washes away soil and grass without reducing the yeast flora of the fruit or causing any appreciable fall in the sugar content of the juice.

Pomace Handling.

Pressed apple pomace should be dealt with promptly, for within a few hours it can become a serious infective source not only of micro-organisms but also of fruit flies (*Drosophila* spp.) which carry acetic bacteria throughout the factory.

Wet pomace needed for treating slightly acetic cider should be mixed with such cider immediately or its curative effect will be lost (3, 4) : if awaiting sale to farmers it should not be left in exposed heaps but should be mechanically conveyed into an enclosed silo sufficiently raised to allow the passage of carts underneath.

Where pomace is dried, the drying machine should be of sufficient capacity to keep pace with presses ; both wet and dried pomace should be held in closed bins or silos. Wherever possible the pomace should be moved in closed conduits in order to keep floors clean, otherwise fine particles will be blown about the factory and spread infection.

Juice Treatment.

Freshly pressed apple juice contains a large number of yeasts, moulds and bacteria and it is essential that only the primary fermenting yeasts be allowed to develop. Aerobic spoilage organisms may be inhibited by filling clean vats with juice and conveying the large volumes of froth formed via a " swan neck " and a hose-pipe directly to the drain ; once froth has ceased to form the " swan neck " should be removed and replaced with a well fitting air lock. This is better than allowing the froth to spread over the tops of the vats or allowing it to remain in a vat only partially filled with the fermenting juice. The once popular practice of keeving may be used if the process is not allowed to continue for more than one week.

In the West Country the preponderance of cider apples of low acidity makes it essential that cider-makers should retain acidity by preventing the growth of malo-lactic bacteria : these bacteria can be destroyed by adding 150 p.p.m. of sulphur dioxide to the juice (5, 6). On the other hand cider-makers in the Eastern Counties, who must perforce make greater use of fruit of higher acidity, rely on the malo-lactic fermentation to reduce excess acid (7) : for these acid juices only 100 p.p.m. sulphur dioxide should be used.

The addition of either 100 or 150 p.p.m. sulphur dioxide to juice has further important advantages since it destroys film yeasts, acetic and oiliness bacteria, leaving only the primary fermenting yeasts (6). The numbers of these yeasts are at first reduced so that there is a delay of 7–14 days in the onset of fermentation ; once the yeasts have grown in sufficient quantity fermentation begins and continues normally.

In view of the precautions required to select the desired members of the natural flora it might appear more logical to sterilise the juice and to add a pure yeast culture. The whole question of sterilisation treatments has been discussed in detail elsewhere (6). It involves not only sterile filtration or flash pasteurisation of the juice but also sterilisation of vats and pipelines. Moreover, the cider is not protected from subsequent infection. While this procedure is possible with juices of high specific gravity that are to be used for the most expensive grades of cider, it is not at present economical for general use. One advantage of the simple sulphiting treatment is that the residual sulphur dioxide protects the juice from infection during fermentation : its use is common practice in the wine industry (8).

Fermentation.

It is essential to control the rates of fermentation of the juices so that the vintage quality of the cider is maintained and vats, labour and equipment

are used to the best advantage. The rate of fermentation is controlled by the micro-flora, nutritional status of the juices and the temperature inside the vats.

Provided the juice contains adequate yeast nutrients, the use of sulphur dioxide, with or without the addition of a pure yeast, enables the rate of fermentation to be more effectively controlled by varying the temperature. Temperature control forms an important part of Continental cider-making practice (13) although it has not been used to any extent by English cider-makers. But even when the yeast flora and temperature are controlled, the rates of fermentation of individual juices will vary, since juices vary in their nitrogen and thiamine content. If temperature control is not possible, adjustment of the nutritional status of the juice offers an alternative method for correcting the rate of fermentation of a juice. Details of this method are given in an accompanying article (9).

During fermentation the specific gravity should be determined frequently and an average loss of one degree of S.G. per day should be maintained, i.e. a fall of thirty degrees in the first month should be aimed at. Rapid fermentations should be checked by cooling, and excessively slow fermentations hastened by increase in temperature or addition of nutrients, until the desired rate of fermentation is attained. When pressure vessels are used for fermentation, control is rendered more exact since increased CO_2 pressure reduces the rate of fermentation (10). How far these measures could be adopted by the industry at present is open to question but they should be borne in mind and existing facilities used to the best advantage.

Storage of Cider.

In the West Country fermentation should be stopped at a specific gravity of 1,005. This is best done by centrifuging and filtering through pulp or by direct filtering using kieselguhr. The clarified cider should then be stored in full air-tight vats preferably made of concrete or steel, suitably lined. It will keep better if the storage cellar is maintained at or below 40°F. as bacterial growth is inhibited at this temperature. If 150 p.p.m. sulphur dioxide was added initially to the juice to suppress unwanted organisms, no further addition is needed. If it was not then added, 150 p.p.m. should be added to the clarified dry cider at the time of storage. The small amount of sugar remaining allows a very slow fermentation to set in, sufficient to saturate the cider with carbon dioxide and to prevent acetification or oxidative changes. Alternatively, the cider in the vats can be kept saturated with carbon dioxide by direct injection. This will, however, be economical only if the carbon dioxide evolved during the main fermentation is collected, purified and stored, as is done in many breweries. The gas can also be used for carbonating bottling cider (2).

In the Eastern Counties, where a malo-lactic fermentation is required, it is an advantage to ferment the cider to dryness, to leave it on the lees and to maintain higher storage temperatures. At temperatures between 60–65°F. the malo-lactic bacteria normally grow rapidly ; at lower temperatures their growth is necessarily slower. While deacidification is taking place the vats should be kept completely filled, but in any event the cider should never be allowed to remain on its lees for more than one month. When the acidity has been reduced to the required degree the cider should be clarified and stored

as detailed above. If the reduction of acidity is incomplete after one month, the cider should be racked and given a further period of storage without any addition of sulphur dioxide. In ciders of very high acidity the growth of the bacteria is restricted and it may be necessary to rack after one month and blend with cider of low acidity (7). Under these more favourable conditions the acidity of the cider should fall on storage. Leaving the cider on its lees for a month will increase its nitrogen content to some extent due to yeast autolysis (9). This is unavoidable if the acidity of the cider is to be reduced to a reasonable level. It follows that particularly great care will be needed to avoid yeast infection at the time of bottling.

The stability of cider during storage is dependent both upon the conditions of storage and on the degree of microbiological control during fermentation. In the absence of such control the storage period is fraught with many dangers and the quality of the cider may deteriorate rather than improve (11).

It is essential that an adequate vat capacity be provided in every factory and this is best achieved by using blocks of square concrete vessels, suitably lined. In many cider factories there is insufficient storage capacity for the volume of cider currently produced and as a result the fully fermented material may be left on the lees for many months. This may lead to the development of harsh flavours from yeast autolysis, to uncontrolled malo-lactic fermentations and outbreaks of oiliness. Autolysis also liberates nitrogenous compounds and the cider is more liable to re-ferment when sweetened.

Care of Final Products.

Draught Cider.

Cider-makers have rarely given the same care to their casks as have the brewers. Often, in the past, cider has been put into casks that have been merely drained or swilled out with water (12). It is essential that, immediately prior to filling, casks should be cleaned and sterilised, following the instructions given in the *Cider-Making Bulletin* (4). All empty casks should be re-bunged as soon as they have been emptied so that the interior of the cask may remain moist and prevent the formation of dried-on deposits that are difficult to remove. When casks are returned to the factory they should be examined carefully by an experienced workman, and segregated into groups so that they can receive the appropriate cleansing treatment. Too often disorders are brought into the factory by insufficient attention to returned infected ullage.

As draught cider is not sterile-filtered into casks, it can contain, under present conditions, a wide variety of spoilage organisms. Draught cider kept in a warm room must be consumed within 7–14 days once the cask is tapped, otherwise its flavour will deteriorate due to the action of film yeasts or acetic bacteria. If the cask of cider is stored in a cool cellar its storage life will be prolonged, but the temperature is rarely low enough to retard unwanted microbial growth for an extended period.

Fresh cider, as made by the methods outlined in this article, will contain not only yeasts but possibly sickness bacteria, capable of developing when the cider is sweetened for sale in cask. If, however, the dry cider is stored for 6–9 months the bacteria will die out and it will then contain only yeasts.

Slightly carbonated cider is to be preferred to the completely still product since carbonation minimises oxidation changes and makes the cider more

attractive. The cider can either be carbonated directly or be conditioned naturally. Natural conditioning can be encouraged by sweetening the cider slightly (4 to 6 degrees of S.G.) with sugar syrup and adding a pure culture of a flocculating yeast. The yeasted cider should be kept in the blending vat until fermentation has set in before pumping into casks. At the point of sale the cask should be stillaged for 24-48 hours before tapping and it should not be spiled. With old cider it may sometimes be necessary to add small quantities of nutrients at the time of sweetening; the need for this can be determined beforehand by the small scale tests for slow fermenting ciders given in an accompanying paper (9).

Bottled Cider.

With the exception of naturally-conditioned ciders, now rarely made, bottled ciders should be free from living organisms. In the traditional method of making champagne cider this freedom is ensured by leaving the cider in bottle for a number of years before disgorging the yeast deposit: the long continued absence of sugar and the high gas pressure together kill all organisms.

When champagne cider is made in large pressure vats it is sterile filtered and bottled aseptically (i.e. by the cold sterilisation method). Most bottled ciders are carbonated directly and stabilised either by the cold sterilisation process or by pasteurisation after bottling. Pasteurisation at 165°F. for 20 min. for pint or 30 min. for quart sizes, is essential for export ciders or if the bottling equipment cannot be sterilised adequately. The treatment need not have any marked effect on flavour if properly carried out. If, however, the bottles are not chilled rapidly after the heating period, an undesirable flavour sometimes develops. The cold sterilisation method yields a fresh-flavoured cider but it is more difficult to operate with unskilled labour. In this process carbonated cider is sterile filtered and forced through a sterile pipeline into a sterile bottling machine and thence into sterile bottles. The main source of infection is the bottling machine, especially the older types that cannot be steamed or are so designed that vital parts cannot be reached with sterilising solutions. Sterilising filters, operated according to the manufacturers' instructions and with the correct grade of filter pad, are highly satisfactory and consistently yield sterile filtrates. Bottles are sometimes a source of infection and each bottle washing machine should have regular maintenance inspection at least once a week. Infection from the atmosphere or from crown corks occurs rarely although perished rubber rings on screw stoppers can cause trouble.

Laboratory Facilities.

To supplement the procedures recommended in this article certain laboratory facilities are needed, but these need involve only a small extension of those usually available. The laboratory tests can, if necessary, be performed by non-scientific personnel, after suitable training; standard solutions for chemical determinations can be purchased. Routine determinations of acidity and sulphur dioxide are essential in factory cider-making: a record of changes in acidity is especially valuable as it gives an indication of the effectiveness of microbiological control methods.

Sterility checks are required on samples of cider taken from the filter, on empty bottles from the washer, and on filled bottles from the filler. Samples from pipelines and vats should be taken by swabbing and from casks by rinsing with sterile water. These samples are either incubated directly or inoculated into sterile liquid or solid media (6) and incubated. These sterility checks would require the following apparatus : a small insulated cupboard maintained at 25°C., a dry-sterilising oven or domestic cooker, an autoclave or steamer and simple laboratory glassware.

Factory Construction and Hygiene.

If a cider factory is well planned and soundly constructed it is more easily maintained in a hygienic condition, especially if equipment is properly sited. Too often, however, cider factories are extensions of farm-type buildings and efficient management with a necessary standard of hygiene is difficult to achieve. Obviously it would be impracticable to rebuild and resite all the equipment in an established cider factory, but some rearrangement is often possible. A scheme for modernising a factory can be spread over a number of years provided that all alterations are made with a well-conceived final plan in view. Factory construction (13) and factory hygiene (4) are discussed in greater detail in the references cited.

Vats for fermentation and storage are perhaps the most important pieces of equipment in the cider factory. In England cylindrical wooden vats are still in general use, mainly because of the large amount of capital invested in them. They are difficult to clean, but cleaning can be done efficiently with a high pressure water spray. They should be mounted on brick piers with suitable floor drainage under the outlet valves. The most satisfactory vats for cider-making are undoubtedly square concrete tanks lined with a suitable bitumastic preparation : they can be made air-tight, they can be cleaned easily and efficiently, and can be built in tiers, thus economising in floor space. Cylindrical glass- and plastic-lined steel tanks are equally satisfactory as containers but when they are used a smaller volume of cider is accommodated in a given space.

Cleaning and sterilisation procedures should be laid down not only for floors, vats and casks but also for all equipment coming into contact with fruit, juice or cider. The working parts of the equipment should be overhauled at regular intervals and each machine sterilised before use ; further, each piece of equipment should be cleaned immediately after use.

Microbiological control methods should be developed systematically until all aspects of the cider-making process are covered. When this is achieved not only will the products be improved in quality but disorganisation of production due to the appearance of disorders will cease.

Summary.

It is suggested that a stricter control of the growth of yeasts and bacteria at all stages of cider-making would improve the quality of cider and do much to eliminate losses due to disorders. It is shown how improvements could be made in factory methods by attention to the following points :—

(1) Fruit selection and storage.

(2) Prompt disposal of pressed pomace.

(3) The addition of sulphur dioxide for the control of micro-organisms.
(4) Methods for controlling the rate of fermentation.
(5) The suppression or utilisation of malo-lactic fermentation according to the type of fruit available.
(6) The use of natural conditioning in the production of draught ciders.
(7) The adoption of adequate methods for ensuring sterility in bottled ciders.
(8) The maintenance of hygienic conditions at all stages of cider-making.

REFERENCES.

(1) Benvegnin, L., Capt, E. and Piguet, G. (1947). *Traité de Vinification*, Librairie Payot : Switzerland.
(2) Challinor, S. W. (1948). *Ann. Rep. Long Ashton Res. Sta.*, 216.
(3) Barker, B. T. P. (1907). *Rep. of Nat. Fruit and Cider Inst.*, 24.
(4) *Notes on Domestic and Farm Production of Cider and Perry* (1951), Research Station, Long Ashton.
(5) Phillips, J. D. (1952). *Ann. Rep. Long Ashton Res. Sta.*, 137.
(6) Beech, F. W. (1952). *Ibid.*, 125.
(7) Carr, J. G. (1952). *Ibid.*, 144.
(8) Joslyn, M. A. (1953). *Food Technology*, **7** (11), 30.
(9) Burroughs, L. F. (1953). *Ann. Rep. Long Ashton Res. Sta.*, 184.
(10) Geiss, W. (1952). *Gezügelte Gärung*. J. Wagner & Sons: Frankfort-on-Main, Germany.
(11) Pollard, A. (1953). *Science and Fruit*, University of Bristol, 56.
(12) Barker, B. T. P. (1953). *Ibid.*, 29.
(13) *The Cider Factory : Plant and Layout* (1953). Technical Publication No. 2 of the Rural Engineering Service of the French Ministry of Agriculture. Translated by V. L. S. Charley, P. M. Mumford and E. J. Martin. Leonard Hill Ltd. : London.

BIBLIOGRAPHY.

Bunker, H. J. (1952). Biological Control in Brewing and Bottling. *Laboratory Practice*, **1** (8), 354.
Comrie, A. A. (1953). Biological Control in the Brewery. *Brewers' Guild J.*, **39**, 4.
Beattie, G. B. (1952). Bottle Washing Test Techniques. *Bottling*, 3.
Osgood, G. (1949). Sterile Filling. *European Brewing Convention, Lucerne*, **1**, 202.
Whitley, W. A. (1948). Routine Biological Tests in the Brewery. *J. Inst. Brew.*, **54** (1), 21.
Wiles, A. E. (1949). Yeast Infection of Bottled Beer. *Ibid.*, **55** (3), 165.
Clerck, J. de (1950). Penetrating Sterilisation. *Ibid.*, **56** (6), 353.
Morris, O. (1951). Fundamentals of Some Modern Bottling Plants. *Ibid.*, **57** (4), 236.

THE COMPOSITION OF THE JUICES OF SOME VARIETIES OF CIDER APPLES.

By L. F. BURROUGHS and YVONNE P. MAY.

I. Varieties Recommended for General Planting.

In the late 1940's, the declining acreage of cider orchards and the lack of adequate replanting was causing concern (1, 2). The situation had been aggravated during the war years and immediate action was necessary to safeguard future supplies of fruit for the cider industry. Accordingly, in 1947 the Cider Advisory Committee of the Research Station, in consultation with the National Association of Cider Makers, the National Farmers' Union, the National Agricultural Advisory Service and the County Councils of the cider-making counties, published a list of fourteen varieties recommended for general planting, together with a supplementary list of varieties suitable in certain counties (3).

Although the varieties were broadly classified according to the acid and tannin contents of the juice, it is of interest to cider makers to know their juice composition more closely. In this paper, figures are given (Table I) showing the average specific gravity, acid and tannin contents, and rate of fermentation of the varieties recommended for general planting ; most of the analyses from which these averages are calculated have been published in previous Annual Reports.

Some of these varieties have been widely grown for many years and their average juice composition can be stated fairly accurately ; others are of more recent introduction and for these the information is limited. Several of the varieties were planted in the 1935-6 series of cider bush-plots (4) and records of their juice composition, including nitrogen content, are available over a number of years ; these are given separately from those for standard trees, since the method of culture may affect the juice composition.

The average specific gravities of most of the varieties are in the range 1·050–1·055, the only notable exception being Kingston Black which is high and is discussed separately below. The average acid and tannin contents are characteristic of the varieties. Most of the varieties have medium rates of fermentation, in the region of 3–4 degrees specific gravity per day at 25°C. ; exceptions to this are the varieties Court Royal and Bulmer's Norman, which are characteristically fast-fermenting, and Stoke Red which is slow-fermenting. The average nitrogen contents of the juices from bush trees are directly related to the rates of fermentation ; no nitrogen data are available for juices from standard trees.

Juices from bush trees have slightly higher specific gravities and tannin contents than those of the same varieties from standards and, except for Improved Foxwhelp, slightly lower acidities and rates of fermentation. The evidence for these differences cannot, however, be regarded as conclusive since the sources of fruit of the two types were unrelated.

Although the figures for average juice composition of the varieties conform with general experience, they can be regarded only as approximate estimates. The juice composition of a given variety varies from one orchard to another

and from season to season. The effect of one seasonal factor, the amount of sunshine, on the specific gravity of Kingston Black juice is shown in the following section.

TABLE I.

AVERAGE COMPOSITION OF JUICES OF CIDER VARIETIES RECOMMENDED FOR GENERAL PLANTING.

Variety	Standard or bush	No. of samples	Specific gravity	Titratable acidity % malic acid	Tannin %	Rate of fermentation. Degrees S.G. per day at 25°C.	Nitrogen mg. N/100 ml.
Court Royal	Std.	11	1·052	0·21	0·11	7·0 (7)	—
Sweet Alford	Std.	102	1·052	0·22	0·15	4·3 (84)	—
	Bush	49	1·056	0·20	0·18	3·3	8·7 (38)
Sweet Coppin	Std.	17	1·055	0·22	0·14	4·3 (10)	—
Bulmer's Norman ..	Std.	11	1·052	0·32	0·25	6·9	—
	Bush	18	1·058	0·22	0·29	6·0	14·8 (14)
Tremlett's Bitter ..	Std.	14	1·052	0·28	0·34	2·9 (10)	—
Yarlington Mill	Std.	37	1·050	0·23	0·29	3·8 (26)	—
	Bush	58	1·055	0·22	0·34	3·2	7·0 (44)
Ashton Brown Jersey ..	Std.	9	1·051	0·15	0·19	2·7 (6)	—
Dabinett	Std.	39	1·054	0·22	0·25	5·4 (33)	—
	Bush	59	1·061	0·15	0·32	4·0	10·2 (52)
Tardive Forestier ..	Std.	11	1·052	0·29	0·47	5·7 (8)	—
	Bush	19	1·054	0·22	0·54	4·1	10·6 (12)
Improved Foxwhelp ..	Std.	3	1·045	0·73	0·17	1·1	3·7
	Bush	9	1·051	0·91	0·22	3·8	8·8
Kingston Black	Std.	308	1·061	0·59	0·19	4·3 (243)	—
	Bush	31	1·064	0·50	0·21	3·8	6·0 (22)
Stoke Red	Bush	26	1·053	0·64	0·31	1·7	4·1 (22)
Backwell Red	Std.	12	1·053	0·70	0·08	3·9 (9)	—
Crimson King	Std.	21	1·054	0·57	0·14	5·8 (18)	—

(In the columns for rates of fermentation and nitrogen content, figures in brackets indicate the number of samples in the average where this differs from the number in column 3).

As a result of the variability in composition of individual samples, a reliable estimate of the average composition of a variety can be obtained only from a large number of samples. From the statistical examination of 308 samples of Kingston Black, it is shown in the following section that more than 50 samples of fruit are required in order to estimate the average specific gravity of the variety with a precision of ± 5 degrees. Other juice constituents show the same order of variability.

There is no reason to believe that the variability in other varieties is substantially different from that found in Kingston Black. For many of the varieties in Table I, therefore, the number of analyses available is insufficient to give accurate values for the average juice composition. Nevertheless, the figures quoted indicate the type of juice generally to be expected from a given variety.

II. Variation in Juice Composition of Kingston Black.

The large number of analyses for Kingston Black (standard trees) collected over many years, makes it possible to study some of the seasonal factors influencing juice composition. Furthermore, since the juices were derived from all districts of the cider-making countries over many years, the data can be used to calculate the variability occurring within the variety.

TABLE II.

AVERAGE COMPOSITION OF KINGSTON BLACK JUICE FOR THE YEARS 1903–1937.

	No. of samples	Specific gravity	Titratable acidity % malic acid	% Tannin	Rate of fermentation
1903	10	1·058	0·50	0·21	—
1904	3	1·063	0·57	0·11	—
1905	1	1·064	0·61	0·15	—
1906	4	1·068	0·68	0·19	—
1907	3	1·057	0·45	0·17	—
1908	27	1·065	0·54	0·20	—
1909	11	1·057	0·55	0·13	4·5 (6)
1910	17	1·063	0·61	0·18	4·1 (11)
1911	14	1·076	0·57	0·29	5·1
1912	13	1·059	0·42	0·15	4·4
1913	4	1·063	0·58	0·17	4·5
1914	13	1·059	0·46	0·19	4·5 (11)
1915	1	1·050	0·42	0·16	4·8
1916	6	1·055	0·55	0·21	3·0
1917	1	1·048	0·67	0·17	—
1919	8	1·059	0·60	0·20	3·3
1921	14	1·074	0·60	0·20	5·1 (11)
1922	10	1·057	0·60	0·20	3·2
1923	4	1·060	0·55	0·16	7·1
1924	6	1·056	0·67	0·21	2·5
1925	5	1·065	0·80	0·29	3·8
1926	12	1·063	0·69	0·19	5·8
1927	21	1·054	0·62	0·17	3·3
1928	8	1·058	0·56	0·18	4·7
1929	12	1·069	0·76	0·22	4·2
1930	3	1·049	0·50	0·14	5·3
1931	9	1·057	0·65	0·23	5·6
1932	8	1·061	0·75	0·22	4·4
1933	15	1·073	0·73	0·23	5·4
1934	4	1·074	0·66	0·20	5·2
1935	11	1·060	0·62	0·19	4·8
1936	23	1·049	0·51	0·16	3·5
1937	7	1·066	0·66	0·19	3·6
Average ..	308	1·061	0·59	0·19	4·3 (243)

(Figures in brackets following the rates of fermentation, indicate the number of samples in the average where this differs from the number in column 2).

(a) *Seasonal Variation.*

Table II shows the average composition of all samples received at Long Ashton in each year from 1903 to 1937. The range of average juice composition over this period was : Specific gravity, 1·048–1·076 ; Acidity, 0·42–0·80 ; Tannin, 0·11–0·29 ; Rate of fermentation, 2·5-7·1. These analyses have been examined in relation to the sunshine and rainfall records for the four months June to September in each year. It must, however, be remembered that only major variations in weather can be expected to show effects on the average juice composition since the data are subject to the following limitations :—

(1) The samples were derived from widely different sources in different years and the analyses are therefore influenced not only by weather, but also by variations in soil, site, age and nutrition of the trees.

(2) The number of samples examined was very different from year to year and this affects the significance to be attached to the yearly average juice composition.

Examination of the figures showed that there was a general tendency for specific gravity to be related directly with hours of sunshine and, to a less extent, inversely with rainfall ; other juice characteristics appeared to be independent of the weather. Fig. 1 shows the relation between average specific gravity and hours of sunshine in each year from 1903 to 1937. There is a general similarity in the occurrence of peaks in the two curves, specific gravities over 1·065 being obtained only when there were more than 800 hours of sunshine. On the other hand, in years of low sunshine, specific gravities were not always abnormally low (contrast 1912 and 1931 with 1936).

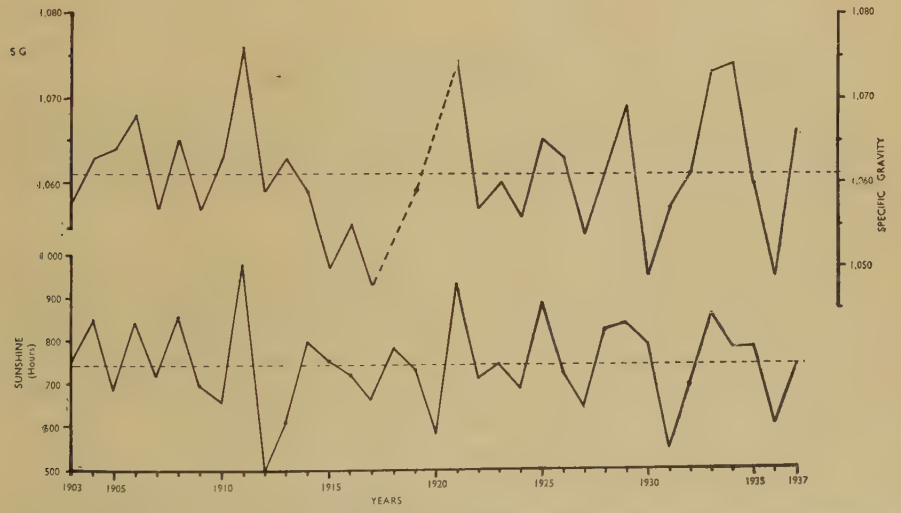


Fig. 1. Seasonal variation in specific gravity of Kingston Black juice : effect of sunshine (June to September).

Notes.—1. Horizontal dotted lines indicate average specific gravity (1061) and average sunshine (740 hours).

2. No juice samples were available in 1918 and 1920.

The relationship between specific gravity and sunshine for Kingston Black juice probably holds also for other varieties. Thus, in years when Kingston Black gave very high or very low gravities, a similar tendency was usually noted for Sweet Alford, of which 102 analyses were available.

(b) *Statistical Examination of Variability in Composition of Kingston Black Juice.*

The range of juice composition within the variety is seen to be very wide (Table II) even on the basis of seasonal averages, and would be even wider for individual samples of juice. The data for Kingston Black have therefore been examined statistically to determine the reliability of the calculated average composition. The results are expressed in Table III as the 95% confidence limits for the means; this expression implies that, if a number of similar sets of analyses were available, only one in twenty would give a mean outside the range indicated in the table.

TABLE III.

COMPOSITION OF KINGSTON BLACK JUICE—95% CONFIDENCE LIMITS FOR MEANS OF 308 SAMPLES.

(95% confidence limit = mean ± e).

	Specific gravity	Titratable acidity	Tannin %	*Rate of fermentation
Mean ..	1·0611	0·594	0·194	4·33
e ..	±0·0022	±0·016	±0·006	±0·20

(*Only 243 samples were available for rates of fermentation).

As an example, the figures show that there is a 95% probability that the true mean specific gravity is between 1·0633 and 1·0589. The limits shown in Table III are satisfactorily narrow, due to the large number of samples available, and the means can thus be regarded as reliable estimates of the average juice composition of the variety.

If the number of samples had been smaller, the confidence limits would have been correspondingly wider and the means would probably have differed from those in Table III. The type of variation that would be given by smaller numbers of samples can be calculated from the Kingston Black data, knowing the means and the variability of the 308 samples. The uncertainty involved in calculating the mean specific gravity from a smaller number of samples, taken at random from the same data, is indicated in Table IV.

Thus, if only 10 samples of juice were available, there is a chance of 1 in 20 that their mean specific gravity would be outside the range 1·0475–1·0747 (i.e. 1·0611 ± 0·0136) whereas for 300 samples the range would be only 1·0589–1·0633. More than 50 samples are required if the mean specific gravity is to be estimated with a precision of ± 5 degrees. The reason for this variability is that a number of the 308 samples were of very high or very low specific gravity and these cannot be ignored.

TABLE IV.

EFFECT OF NUMBER OF SAMPLES (N) ON 95% CONFIDENCE LIMITS (MEAN ± e) OF ESTIMATED MEAN SPECIFIC GRAVITY (1·0611).

N	e	N	e
10	0·0136	50	0·0054
15	0·0107	100	0·0038
20	0·0090	150	0·0032
30	0·0071	200	0·0028
40	0·0063	300	0·0022

The variabilities of the acid and tannin contents and rates of fermentation are not quoted ; they were, however, of the same order as the variability of the specific gravity. The implications of this on the reliability of the averages quoted in Table I have been discussed in a previous section.

Summary.

(1) The average juice composition of 14 varieties of cider apple is presented.
(2) Seasonal variation in the juice composition of Kingston Black is examined in relation to weather conditions. There was a tendency for specific gravity to be directly related with the amount of summer sunshine.
(3) The variability of composition of 308 samples of Kingston Black juice has been examined statistically.

Acknowledgments.

The authors are indebted to Mr. G. M. Clarke for the statistical calculations and to Miss Shirley J. Locke for assistance in compiling the data. Acknowledgment is also made to Mr. G. E. Clothier for the weather records for Long Ashton and to the Medical Officer of Health of Weston-super-Mare for sunshine records prior to 1920.

REFERENCES.

(1) Barker, B. T. P. (1948). *Herefordshire Agricultural Journal*, **11,** 17.
(2) Ball, E. (1947-48). *J. Min. Agric.*, **54,** 107.
(3) Barker, B. T. P. (1947). *Ann. Rep. Long Ashton Res. Sta.*, 19.
(4) Swarbrick, T. (1941). *Ibid.*, 11.

THE ROLE OF NITROGEN AND VITAMIN B_1 IN CIDER-MAKING.

By L. F. BURROUGHS and A. POLLARD.

The rate of fermentation of an apple juice, a character of great importance in cider-making, is largely determined by its content of nitrogen and of vitamin B_1 (thiamine*). The better cider apple varieties normally yield medium or slow-fermenting juices while juices from culinary and dessert varieties ferment more rapidly. In general, excessively fast fermentations produce ciders that are harsh and lacking in flavour and, when sweetened with sugar, these ciders are sometimes liable to re-ferment. On the other hand a very slow-fermenting cider disorganises factory routine and is often susceptible to bacterial disorders, especially if the acidity is low. It is important therefore to control the rate of fermentation of ciders both to maintain the quality of the product and to ensure efficient processing.

The rate at which a juice will ferment depends on the amount of yeast growth it is able to support, on the strains of yeast present and on the temperature. The use of controlled temperatures and the selection of suitable yeasts are dealt with in another article in this report (1).

In the absence of facilities for varying the temperature, much can be done to control the fermentations by other means if the factors affecting yeast growth are understood. The present paper gives a general account of the influence of nitrogen and thiamine on yeast growth in cider ; this is followed by practical recommendations for the control of fermentations, based on these principles.

The Course of Yeast Growth in Fermenting Ciders.

It has been known for many years that the amount of yeast growth that a juice is able to support is related to its nitrogen content (2) and this has been confirmed and further investigated in recent studies (3, 4). Apple juices differ greatly in nitrogen content ; this is partly a varietal effect and partly due to the conditions under which the fruit is grown. Most cider apple varieties contain between 3–15 mg. nitrogen per 100 ml. of juice, while the range for culinary varieties is appreciably higher. The greater part of this nitrogen is in the form of amino-acids, asparagine being particularly prominent in high nitrogen juices. These nitrogenous compounds are readily assimilated by yeasts and utilised for growth.

In a juice of medium nitrogen content, e.g. 10 mg.N/100 ml., most of the yeast growth occurs during the early part of the fermentation. Growth may then be arrested by lack of available nitrogen while the specific gravity is still above 1,025, and fermentation to dryness is subsequently carried out by the yeasts already formed. As a result of the yeast growth, the soluble nitrogen of a cider of this type is reduced to the region of 1–2 mg.N/100 ml., which is sufficiently low to prevent further fermentation when the cider is sweetened for sale. It must be emphasised that the resistance of a bottled cider to

*In accordance with modern practice vitamin B_1, previously called aneurin, will in future be referred to as thiamine.

fermentation by yeasts, following chance infection at the time of bottling, depends largely on its very low nitrogen content. This low level of nitrogen will be maintained, however, only if the cider is removed from the lees as soon as it is approaching dryness since, shortly after yeast growth ceases, the soluble nitrogen content of the cider begins to increase as a result of autolysis of the dead yeast cells.

The general course of the utilisation of soluble nitrogen for yeast growth in a fermenting cider, together with the accompanying changes in specific gravity, is illustrated in Fig. 1. The graph also shows the increase in soluble nitrogen due to autolysis.

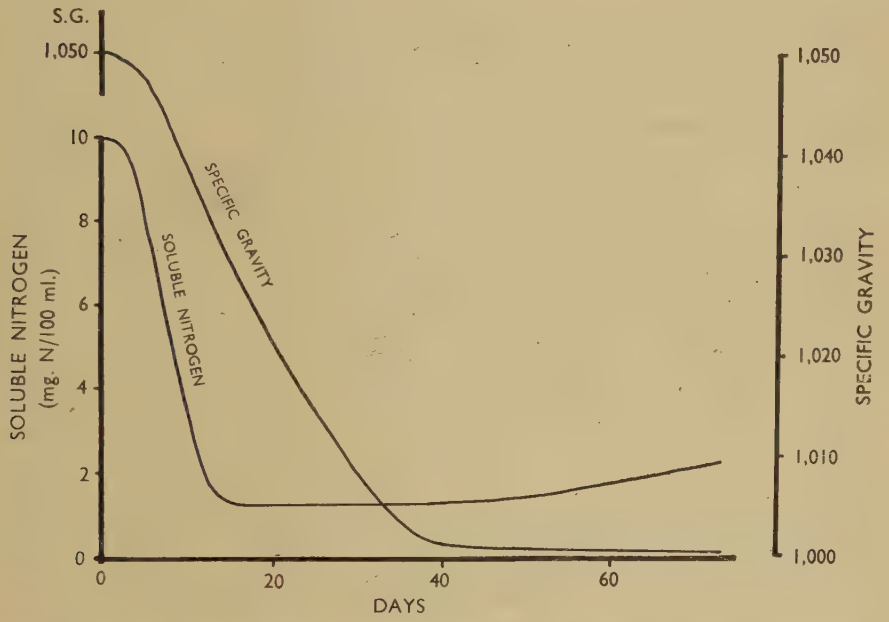


Fig. 1. Changes in soluble nitrogen content of a cider during yeast growth and fermentation.

The amount of nitrogen liberated into the cider as a result of autolysis is naturally proportional to the amount of yeast present and to the duration of its contact with the cider. With a fast-fermenting cider containing a heavy yeast crop it is therefore particularly important that it should be removed from the lees as soon as possible. This is best done by centrifuging or filtering, but if neither treatment is possible the cider may be racked. The cider maker normally regards racking as a means of clarification, but if the operation is delayed until all the yeast has sedimented the degree of autolysis may be serious. The emphasis should always be on maintaining a low nitrogen content in the cider; clarity is of secondary importance and can be improved by racking or filtering at a later date.

In addition to nitrogen, the yeasts occurring in a fermenting cider require thiamine for their growth. Thus it has been found that in juices of high nitrogen content (20–30 mg.N/100 ml.) yeast growth may be limited by thiamine deficiency. The amount of yeast growth may be sufficient to cause a rapid fermentation to dryness but not sufficient to utilise all the available

nitrogen in the cider. Such a cider, containing a high level of nitrogen, would be unstable if sweetened with sugar, especially if blended with other ciders. To obtain a stable cider from a juice of this type it is necessary to reduce the nitrogen content in two stages. A large part of the nitrogen can be removed as yeast by centrifuging at an early stage in the fermentation ; if thiamine is then added to the centrifuged cider, further yeast growth is encouraged and the soluble nitrogen content of the cider is reduced to the desired minimum.

The converse problem of a very slow-fermenting cider arises chiefly from a deficiency of nitrogen and is much easier of solution. It is merely necessary to add nitrogen in the form of ammonium sulphate or phosphate with sometimes a trace of thiamine. It is important, however, not to add excessive amounts of ammonium salts, otherwise the problems of a high nitrogen cider may be provoked ; additions of thiamine are probably less critical since an excess is readily assimilated by the yeasts. Whether the cider requires thiamine in addition to nitrogen can be ascertained by a preliminary test as described later.

Occasionally the addition of nitrogen and thiamine to a slow-fermenting cider may not bring about the desired increase in fermentation. The same difficulty may be found with perry. An excellent example of this was found at Long Ashton in 1952 with a vat of Oldfield perry that had lost only five degrees of specific gravity in sixteen weeks. Preliminary tests showed a strong requirement for both nitrogen and thiamine but when these were added to the vat the response was much less than expected. Further tests showed that it was also necessary to aerate the perry in order to promote a healthy growth of yeast. After 48 hours aeration there was a striking improvement in yeast growth and in the microscopic appearance of the yeast cells ; fermentation subsequently proceeded at a steady rate. It must be emphasised, however, that this aeration procedure is recommended only where preliminary tests have shown it to be necessary, since under ordinary circumstances it would encourage acetification.

Practical Control of Cider Fermentations.

Since the cider maker is normally unable to follow the progress of yeast growth in his ciders by nitrogen determinations, the following suggestions are made for the treatment of very fast- and very slow-fermenting ciders. The aim should be to obtain a rate of fermentation of about one degree of specific gravity per day.

A useful indication of the probable rate of fermentation of a juice can be obtained by incubating a sample at 25°C. and taking the specific gravity at daily intervals. It is not possible to quote an exact relationship between fermentation of the incubated sample and of the cider in the vat, since the vat temperature is uncontrolled and, in any event, will increase appreciably if the fermentation becomes vigorous. Nevertheless, a little experience will enable the cider maker to classify his juices into fast-, medium- and slow-fermenting on the basis of a few days incubation. Under factory conditions the routine testing of every juice is perhaps an ideal difficult to achieve but the information gained is particularly valuable in giving warning of a fast fermentation. The difficulty of obtaining a representative sample from a large vat can be overcome by having a small take-off tube on the main juice line so that a sample is collected continuously as the vat is being filled.

Treatment of Fast-fermenting Ciders.

If the incubation test indicates that the juice will ferment rapidly, the specific gravity of the cider in the vat should be closely watched. Even a fast-fermenting cider usually shows a lag period in the vat before rapid fermentation commences and this should allow the cider maker time to arrange for the appropriate treatment.

Once fermentation sets in, if the specific gravity falls by more than three degrees per day the cider should be centrifuged when the S.G. has fallen by 10–15 degrees. The rate of flow through the centrifuge should be as fast as possible so that, while most of the yeast is removed, sufficient is left in the cider to provide an inoculum for further yeast growth. Fermentation will be checked until more yeast growth takes place ; if fermentation does not start again within a few days, the addition of 1 gram of thiamine hydrochloride per 1,000 gallons is advisable. The cider should then be allowed to ferment until the specific gravity has fallen to 1,005 and finally be centrifuged to prevent autolysis of the lees. Removal from the lees at a specific gravity of 1,005 is essential for all ciders except those of high acidity in which a malo-lactic fermentation is to be encouraged (1).

Occasionally a juice of exceptionally high nitrogen content may ferment at a rate of five degrees or more of specific gravity per day. Thiamine deficiency is very likely to occur in this type of cider and the addition of thiamine hydrochloride (1 gram per 1,000 gallons) after the first centrifuging will be essential if the soluble nitrogen is to be reduced to a safe level. The second yeast crop will probably be quite large and it is therefore particularly important to centrifuge again when the gravity is 1,005.

Treatment of Slow-fermenting Ciders.

If the *incubated* sample of juice loses less than one degree of specific gravity per day, the cider in the vat will probably be very slow-fermenting. The cider maker may decide to accept this inconvenience, although if the acidity of the cider is less than 0·45% malic acid the risk of bacterial disorders is considerable ; furthermore, fermentations which start slowly may cease before dryness is reached.

Most slow-fermenting ciders will respond to the addition of nitrogen alone, but some also require thiamine and it is always advisable to make a preliminary test for this. To do so requires the following solutions :—

(a) 20 grams ammonium sulphate (B.P.) dissolved in 500 ml. water.*
(b) 0·01 gram thiamine hydrochloride dissolved in 10 ml. water. This solution should be freshly prepared ; if an analytical balance is not available, it can be made up by a dispensing chemist.

To make the test take four one-gallon jars of the cider ; to one add 25 ml. ammonium sulphate solution, to the second add 1 ml. thiamine solution, to the third add both ammonium sulphate and thiamine and keep the fourth jar as an untreated control for comparison. All jars should be full and fitted with fermentation locks. After a few days observe the jars for an increase in turbidity and presence of yeast deposit and, after fermentation has been active for some time, take specific gravities. This will indicate whether the

*Alternatively, dissolve ¾ oz. ammonium sulphate in 1 pint of water and use 1 fluid oz. per gallon of cider.

cider requires nitrogen or thiamine or both. The time required for the test can be reduced if the jars are incubated but, unless results are wanted quickly, it is better to keep them at the temperature of the vat.

The amount of nitrogen to be added to the vat should be adjusted according to the required decrease in specific gravity. For each ten degrees fall in specific gravity use 8 oz. ammonium sulphate (or diammonium phosphate) of B.P. quality per 1,000 gallons; this should be dissolved in a small volume of cider and mixed into the vat. There is no need to vary the amount of thiamine and an addition of 1 gram thiamine hydrochloride per 1,000 gallons is adequate. When the cider has fermented to S.G. 1,005 it should be centrifuged to avoid autolysis.

If the above treatment is applied at an early stage to all very slow-fermenting ciders, the problem of a fermentation ceasing before dryness is reached ("stuck" fermentation) is not likely to arise. When it does occur and nitrogen and thiamine have not been added, present experience suggests that oxygen may be required in addition to nitrogen and thiamine. Under these circumstances, the test as described for nitrogen and thiamine should be extended to include a second set of treatments with the jars only *half-full*, to allow contact with air. These will require half the volumes of ammonium sulphate and thiamine specified above. If any of the treatments in the full jars gives a sufficient increase in yeast growth and fermentation, this is the treatment to be used and there is no need to aerate the vat. On the other hand, if the treatments in the full jars give little or no response compared with those in the half-full jars, then the cider in the vat must be aerated after the required addition of nitrogen and/or thiamine.

The amount of aeration needed is not great and obviously depends on the volume of cider. Where compressed air is available, this can be bubbled into the cider through a long glass or stainless steel tube. Alternatively, sufficient aeration can be obtained simply by pumping the cider over into the top of the vat with as much splashing as possible. Once active yeast growth and fermentation have begun, aeration should be stopped to avoid risk of acetification.

It is realised that in many factories a full programme of controlled fermentation may not be possible owing to lack of vat capacity, centrifuging facilities and labour. Under these circumstances considerable benefit will be gained if attention is concentrated on controlling only the more extreme fermentations and on avoiding autolysis of the lees.

Summary.

(1) The influence of nitrogen and thiamine on the course of yeast growth in a fermenting cider is discussed, with particular reference to controlling the rate of fermentation.

(2) Practical recommendations are made for controlling very fast- and very slow-fermenting ciders.

(3) The need for avoiding yeast autolysis in a cider is emphasised.

REFERENCES.

(1) Beech, F. W. and Pollard, A. (1953). *Ann. Rep. Long Ashton Res. Sta.*, 171.
(2) Grove, O. (1919). *Ibid.*, 20.
(3) Burroughs, L. F. (1951). *Ibid.*, 138.
(4) Burroughs, L. F. (1952). *Ibid.*, 110.

FACTORS AFFECTING THE QUALITY AND STABILITY OF CONCENTRATED FRUIT JUICES: I. BLACKCURRANT AND APPLE CONCENTRATES.

By MARGARET E. KIESER, A. POLLARD, C. F. TIMBERLAKE and MARY R. MOSELEY

The increased production of concentrated fruit juices in the years 1940-45 arose primarily from the need to conserve all available foodstuffs and to provide readily transportable sources of vitamins. While nutritional value was the initial consideration, greater emphasis has since been laid upon flavour and appearance: concentrates can now be prepared that, when diluted, resemble more closely the original juices from which they are derived. These later developments are best exemplified in the production in the U.S.A. of frozen citrus concentrates that offer advantages in distribution and consumption over the fresh fruit or juice (1).

To the English fruit grower products derived from apples and from soft fruits are of greater interest. Concentrated apple juice is extensively produced and is utilised by the cider-maker, by the manufacturer of carbonated beverages and others. The types of concentrate already available would appear to be adequate for many of these present purposes, but concentrates more closely resembling the frozen products produced in the U.S.A. would cater for a wider variety of uses.

The concentration work undertaken at Long Ashton in the first years of the 1939 45 war, using a Kestner Climbing Film Evaporator, emphasised the importance of recovering the volatile essence fraction of the juice. Only when this fraction was returned to the concentrate was the true character of the fruit flavour retained (2). This aspect of concentration has since been extensively developed in the U.S.A., following the work of Milleville and Eskew in 1944 (3).

Satisfactory apple concentrates were prepared in the early tests at Long Ashton, but the production of blackcurrant concentrates presented some difficulties and the products lacked fruit character. This may be ascribed in part to the desire to prepare concentrates of high specific gravity from a highly acid juice (1): at the same time, the volatile essence fraction appeared to be less stable than the corresponding material distilled from apples. Later developments in concentration methods suggested that concentration at a lower temperature and to a lower specific gravity would overcome these difficulties, and tests on these lines were accordingly carried out in 1952 and 1953.

BLACKCURRANT CONCENTRATES.

Preparation of concentrates (1952).

A batch of blackcurrant juice was divided and was given the following treatments:—

1. Concentration at 41-48°C. in a laboratory climbing film evaporator fitted with an ester-stripping device, at Long Ashton.
2. Concentration at 18-20°C. in a pilot model of the "Coolcentrator" of Messrs. Kestner Evaporator and Engineering Company at New Cross, London.

3. Concentration by freezing, undertaken by Dr. R. Gane at the Low Temperature Research Station, Cambridge.

Experimental.

Preparation of the juice.

2 cwt. blackcurrants, variety Westwick Choice, were milled and treated with Pectozyme (0·35%) at 14°C. Although pectin breakdown was incomplete the concentration programme required that the juice be pressed out after 48 hours. It was centrifuged and bulked (13 gallons). One portion was concentrated immediately (Test 1), a second portion was cooled to 0°C. for concentration in London on the following day (Test 2), while the third portion was deep frozen for transport to Cambridge on the following day (Test 3).

The composition of the centrifuged juice was as follows :—

S.G.	1·059.	
pH	2·89.	
Acid	2·9 g./100 g.	(Citric H_20).
Pectin	0·27 g./100 g.	(as Ca pectate).
Ascorbic acid	215 mg./100 g.	(direct 2:6 dichlorophenol-indophenol titration).
(Ascorbic acid in fruit ..	244 mg./100 g.).	

Concentration.

1. Long Ashton Test. 2 gallons of juice were evaporated at a pressure of 20 mm. after stripping the volatiles at a temperature of approximately 60°C. with a heating time of 50 sec. The volatile fraction (3·5% of the juice volume) was concentrated by re-distillation at atmospheric pressure and stored at —23°C. until required for addition to concentrates. The concentrates collected were as follows : S.G. 1·124 (40–41°C.), S.G. 1·240 (45–47°C.) and S.G. 1·257 (45–48°C.).
2. London Test. 6 gallons of juice were evaporated at a pressure of 9–10 mm. and a temperature of 18–20°C. A series of concentrates was collected over the S.G. range 1·187 to 1·290.
3. Cambridge Test. 2 gallons of juice were concentrated by freezing to a soluble solids content of 40%, equivalent to a S.G. of 1·18. This concentrate was immediately brought to 65% soluble solids (S.G. 1·32) by the addition of sucrose.

Analysis of concentrates.

Estimations of titratable acidity and ascorbic acid were made on all concentrates, the latter by direct potentiometric titration with 2:6 dichlorophenol-indophenol. The acidities ranged from 7·6 to 14·4% according to the degree of concentration and the corresponding ascorbic acid values ranged from 431 to 803 mg. per 100 g. The ascorbic acid figures for concentrates of Series 1 and 2 when plotted against the specific gravities fell on the same straight line. The acidity figures similarly fell on a straight line and the values for the Cambridge concentrate were in general agreement.

Thus, within the limits of the test, the relative increases in ascorbic acid and titratable acid with specific gravity appear to have been the same in all concentrates irrespective of the method of concentration. If the degree of

concentration is assessed by the values found for titratable acidity rather than by specific gravity, the losses of ascorbic acid on concentration appear to be about 20%. These figures are based on an estimated mean value of 200 mg. ascorbic acid in the juice at the time of concentration.

TABLE I.

ANALYSIS OF BLACKCURRANT CONCENTRATES (1952).

Sample	S.G.	Acid	Ascorbic Acid		
		(g./100 g.)	Found (mg./100 g.)	Theory (mg./100 g.)	% Loss
Juice (mean value) ..	1·059	2·9	200	—	—
1. Long Ashton : Concentrate	1·124	7·6	431	524	18
,, ...	1·240	13·6	780	938	17
,, ...	1·257	14·4	803	993	19
2. London : Concentrate	1·187	10·9	609	752	19
,, ...	1·240	13·4	725	924	21
3. Cambridge : Concentrate (+ sugar)..	1·322	6·6	360	455	21

Treatment of concentrates.

To make the samples from Tests 1 and 2 comparable with that of Test 3, they were blended to a final standard of specific gravity 1·18, corresponding to a three fold concentration. In order to restore the original fruit character, the appropriate proportion of volatile fraction or of fresh juice (concentrate to juice, 3:1) was added to concentrates of Tests 1 and 2.

As the concentrates were of too low a specific gravity to be stable against fermentation, they were all brought to S.G. 1·32 by the addition of sugar.

The final blends were as follows :—

1a. Long Ashton .. .. Volatiles added.
1b. ,, ,, ... Juice added.
2a. London .. .. No addition.
2b. ,, ... Volatiles added.
2c. ,, ... Juice added.
3. Cambridge .. .. No addition (volatiles already present).

Flavour tests.

Tasting trials were then carried out, one volume of concentrate being mixed with an equal volume of 10% sugar syrup to give a suitable reduction in acidity.

The method of concentration was found to affect the flavour of the concentrates to a lesser degree than had been anticipated. There was a complete absence of pasteurised flavour in the concentrates but the retention of the characteristic fruit aroma appeared to depend almost entirely upon the degree of retention ot the volatile fraction. 2a was of excellent flavour, but lacked aroma. The addition of a portion of fresh juice in 1b and 2c gave products that were better but still lacking in aroma. Concentrates 1a and 2b to which the volatile fraction had been added had an excellent aroma. The best of the series was the freeze-concentrate 3 and the next in order were 2b and 1a respectively. All the concentrates were of high quality and the differences between them would probably be overlooked by the general consumer. After several months storage at 0–2°C. the differences between them became less marked and slight deterioration in quality became apparent. Storage at room temperature resulted in extensive deterioration in flavour and colour and a fall in ascorbic acid content (34% in 9 months in concentrate 3).

These tests indicated that temperature of storage is at least as important as temperature of concentration in conserving quality in blackcurrant concentrates. A further series of concentrates was accordingly prepared in 1953.

Preparation of concentrates (1953).

A batch of de-pectinised blackcurrant juice was concentrated four-fold as in Test 1 (1952) at 40–45°C. to S.G. 1·23 and the concentrates were subsequently stabilised by the addition of sucrose to S.G. 1·32. The different treatments used in their preparation were as follows :—

(a) Juice pre-heated to 90°C. during volatile stripping.
(b) ,, ,, ,, 55°C. ,, ,, ,,
(c) ,, ,, ,, 55°C. ,, ,, ,, with addition of SO_2 (350 p.p.m.) at the time of bottling.

Before the final adjustment of specific gravity each batch of concentrate received an addition of stripped volatiles. Samples of each concentrate were stored at room temperature (about 18°C.), at 0°–2°C. and at —23°C. in crown corked bottles with very small head space, and were tested after 3 months for general quality (visual appearance, flavour and aroma) and for colour changes.

Effects of storage.

General observations. The freshly prepared concentrates were tasted after dilution with an equal volume of 10% sugar syrup. The main differences in flavour noted before storage were that sample (c) containing SO_2 had a less full and rich flavour than sample (b) which possessed to a marked degree the characteristic flavour of the fruit ; sample (a) which had been stripped at the higher temperature (90°) had a slightly softer and cooked flavour. The aroma of all samples was good and fresh and the colour deep red and attractive.

After 3 months storage the following observations were recorded :—

Stored at —23°C. all concentrates retained their red colour and no changes in aroma or in flavour were apparent.

After storage at 0–2°C. slight browning was perceived in concentrates (a) and (b), but not in sample (c) containing SO_2. The flavour of (b) showed little change ; a slight off-flavour was noted in (c) while (a) had developed a marked

acrid flavour. The aroma of the samples showed little change. Storage at 18°C. produced marked changes. All concentrates showed excessive browning, but this was least in (c) containing SO_2. The flavour of (b) and (c) was reminiscent of the cooked fruit while that of (a) was highly unpleasant. All samples had a musty " hay " aroma.

After 6 months storage, the effects of storage temperature were even more marked. Samples stored at —23°C. showed little change, apart from a slight deterioration in flavour in (a) which had been subjected to the highest temperature in preparation. At 0–2°C. the flavour of the concentrates showed little further change, but browning had become more apparent except in concentrate (c) containing SO_2.

At 18°C. both flavour and colour had deteriorated extensively : all samples were unpalatable and had an unattractive brown colour.

Colour changes.

The changes in colour during storage became more apparent when the light absorption of a standard dilution of each concentrate was measured over the range 400 mμ to 600 mμ (Spekker absorptiometer). The main peak of absorption due to anthocyanin occurred near 520 mμ and the figures below give the optical densities over this wave band for the three concentrates after different storage periods at —23°C. :—

Concentrate.	Storage at —23°C. (months).		
	3	5	6
(a) 90°	·475	·423	·400
(b) 55°	·485	·457	·416
(c) 55° + SO_2	·346	·300	·270

After storage at —23°C. for 3 months the intensity of absorption was similar in concentrates (a) and (b) : in the partially bleached concentrate (c), containing SO_2, the absorption was correspondingly less. After further storage at this temperature the intensity of absorption decreased slowly in all concentrates.

At 0–2°C. the loss of anthocyanin was extensive after only 3 months, especially in (a) and (b) where SO_2 was absent. After 5 months at this temperature anthocyanin was present in appreciable amount only in concentrate (c) containing SO_2 ; this sample still showed a slight absorption at 520 mμ after storage for 6 months at 0–2°C.

On storage at 18°C. anthocyanin was no longer detectable in concentrates (a) and (b) after 3 months ; it was still present in traces in concentrate (c) containing SO_2.

The disappearance of anthocyanin from the concentrates was accompanied by an apparent browning, but a corresponding increase in absorption at the shorter wave lengths appeared only after 3 months storage at the highest temperature (18°C.). The changes in colour seen in the samples stored at lower temperatures must therefore be attributed mainly to the destruction of the red component, which allowed the yellow components of the juice to become apparent. After 5 months storage at 18°C., concentrates (a) and (b) showed a slight increase in absorption at 400 mμ, which increased considerably after a further month. This onset of true browning was seen in concentrate (c) containing SO_2 only after 6 months storage.

The colour changes are illustrated by Figure 1 showing the intensities of absorption of concentrates (b) and (c) after storage for 6 months at 18°C.

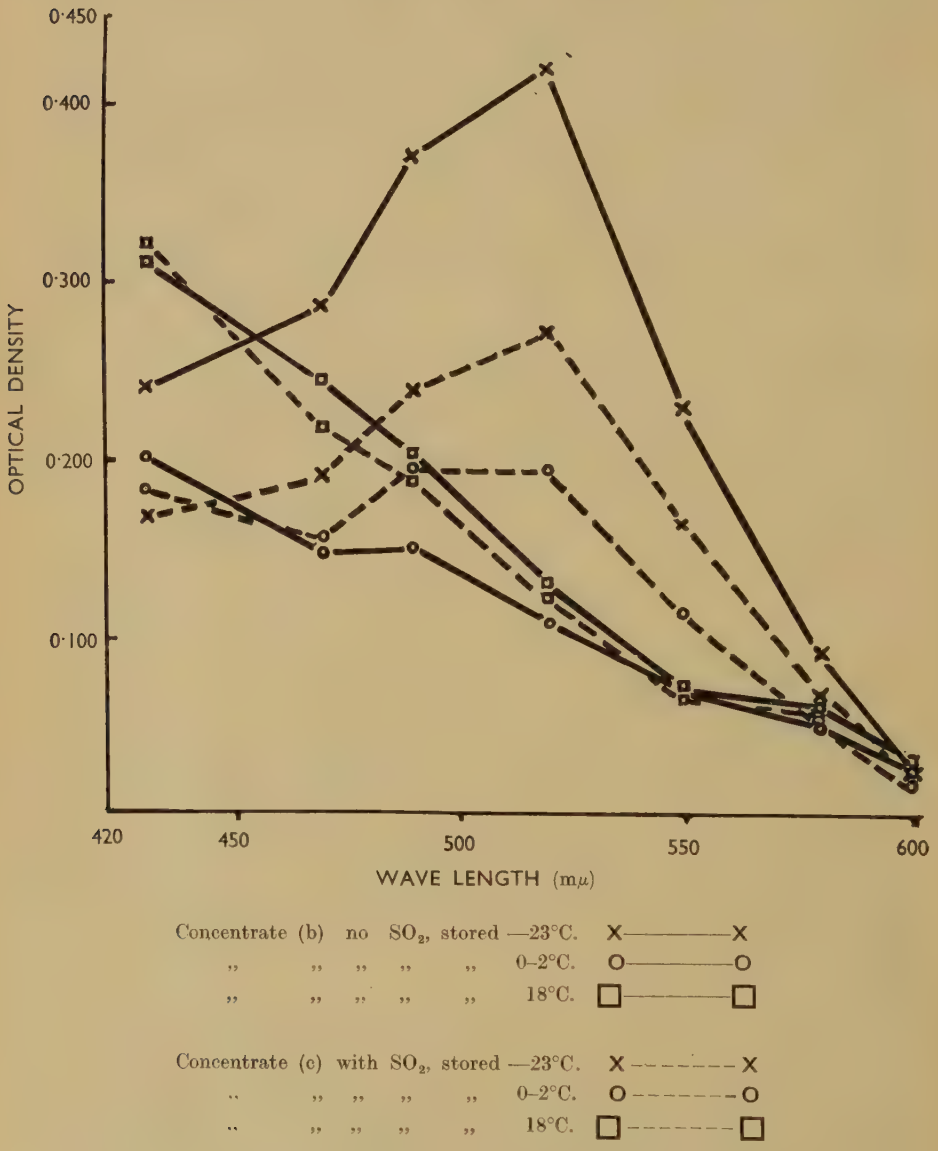


Fig. 1. Colour changes in Blackcurrant Concentrates after storage for 6 months.

Ascorbic acid changes.

The ascorbic acid content of concentrates, as estimated by direct 2:6 dichlorophenol indophenol titration, did not change significantly during storage for 6 months at —23°C.; individual bottles taken for test showed some variation up to 7%. In Table II are given the values for the three concentrates

at the 6 months storage period. The mean value of 350 mg. for the samples stored at —23°C. corresponds to about 90% of the original ascorbic acid content of the juice. Storage losses at 0–2°C. amounted to about 10%; at 18°C. they were of the order of 30%. The method of preparation of the concentrate appeared not to affect the retention of ascorbic acid on storage.

TABLE II.

ASCORBIC ACID CONTENTS AFTER 6 MONTHS STORAGE (mg./100 g.).

	Storage temperature °C.		
	—23°	0—2°	18°
Concentrate (a)	350	315	227
„ (b)	355	328	243
„ (c)	343	309	241

APPLE JUICE CONCENTRATES.

A series of concentrates was prepared from a bulk of mixed culinary and dessert apples to test the effects of the following treatments upon quality and storage changes :—

(i) Pre-heating the juice to 55°C. or 90°C. during volatile stripping.
(ii) The return of volatiles to stripped concentrates.
(iii) The addition of SO_2 (50 p.p.m.) at the time of milling the fruit.

The combinations of these treatments gave, in all, eight batches of concentrate.

One portion of fruit was milled and pressed in the usual way and the juice depectinised overnight before filtration. The second portion had 50 p.p.m. SO_2 added continuously during milling. This treatment had been found by previous experience to inhibit darkening of the juice to a considerable extent during subsequent processing operations. The batches of juice were divided for the different treatments and were all finally concentrated in the laboratory evaporator described above at temperatures not exceeding 45°C. All volatile fractions from the juice without SO_2 were bulked, stored at —23°C. and concentrated by distillation. The appropriate volumes of the distillate were added to the final concentrates from this juice. The volatile fraction from the juice containing SO_2 was treated similarly.

All concentrates fell within the specific gravity range 1·32–1·34 and represented a 6·6 fold concentration of the juice by volume. Before concentration the juice containing SO_2 was pale yellow in colour and retained 15 p.p.m. SO_2 : the control juice was a deeper yellow. After concentration all samples containing SO_2 remained paler than the corresponding samples without SO_2. Soon after their preparation, samples of each concentrate were diluted to the specific gravity of the original juice for tasting tests. The factor producing the greatest effect was the addition or omission of volatiles ; true apple character was lacking where this fraction was not returned. Stripping the volatiles at 90°C. gave a slight " processed " flavour. The addition of SO_2 during milling weakened the flavour of the concentrates.

The samples were stored at —23°C., 0–2°C. and 18°C. in screw-capped bottles with a small air space. The effects of storage for 10 months were :—

At —23°C. there was no marked change in the colour of the concentrates. There was no development of off-flavour and, where volatiles had been added, the concentrates retained apple aroma.

At 0–2°C. there was slight darkening in colour and a perceptible deterioration in flavour, but the effect of adding volatiles was still apparent.

At 18°C. the concentrates had darkened considerably, and a marked off-flavour had developed. The addition of volatiles was no longer apparent, any apple aroma being masked by the stale aroma.

The effect of SO_2 treatment during juice preparation was to reduce the darkening of concentrates and to lessen the development of off-flavours on storage at the higher temperatures.

The concentrates made from juice stripped at 55°C. were not markedly different from those stripped at 90°C., but the latter were slightly better in aroma and flavour at the end of the storage period.

Discussion.

Blackcurrant juice.

The tests on blackcurrant juice concentrates gave results in agreement with those of other workers on similar products, in showing that the maintenance of quality in the concentrate is largely dependent upon the conditions under which it is stored. While direct oxidation can lead to extensive deterioration and loss of ascorbic acid (4), the avoidance of oxidation does not eliminate storage changes. As shown by Pederson and co-workers (5, 6) and by Huelin (7), interactions between the juice components, ascorbic acid, anthocyanins, sugars, acids and amino-acids lead to undesirable changes even in the absence of oxygen. Such reactions are favoured by high storage temperatures and by heat treatments during processing. The products derived from fruits of widely differing composition may exhibit varying degrees of stability, and processing methods may thus need to be modified accordingly.

The 1952 tests showed that a low temperature of concentration caused least damage to the flavour of blackcurrant juice during processing, and that concentration at 18°C., combined with the return of stripped volatiles, gave a product most comparable to that prepared by freezing. The addition of a portion of fresh juice to restore aroma gave a less satisfactory product than did the return of volatiles. Concentrates prepared at 48°C. were not markedly inferior to those prepared at 18°C. and the differences would probably not be perceptible to the average consumer. In these tests concentration did not exceed four-fold ; at higher specific gravities the differences due to heat treatment may prove to be greater.

The advantages due to low temperature concentration were lost if the products were stored at temperatures above 0°C. Temperatures below 0°C. appear to be required if deterioration is to be avoided. Some deterioration was evident even at —23°C., as shown by the changes in anthocyanin, although ascorbic acid appeared unchanged : at higher temperatures anthocyanin changes were extensive. Blackcurrant juice concentrates would appear especially liable to undergo such changes on account of the high levels of pigment and ascorbic acid present (5, 6). The stability of ascorbic acid in the

sweetened concentrates of the 1953 test, which represented only a 2·4 fold concentration of juice, appears greater than that reported by Heiss for more highly concentrated products (8). Deterioration as a whole would be expected to increase with an increase in the concentration of the components, as found in citrus juices (9). The use of sulphur dioxide seems to offer some advantages if blackcurrant concentrates are stored at temperatures near 0°C., or for short periods at higher temperatures, the most noticeable effect being the reduction of browning.

The results of these tests suggest that concentration to a relatively low degree could offer advantages in the bulk storage of blackcurrant juice, the main advantage being the reduced storage capacity needed ; where juice is stored under pressure with refrigeration, as in the Boehi system, this could offer considerable economy. The method of concentration to be adopted will depend upon the quality of concentrate demanded ; on a commercial scale differences due to the method of preparation may be found greater than in the tests described. Low-gravity concentrates will remain free from microbiological spoilage only if stored at low temperature, or under Boehi conditions, unless sugar or preservatives are added. The present tests emphasise the need for low temperature of storage if chemical deterioration is to be avoided.

Apple juice.

In apple juice concentrates ascorbic acid and anthocyanin are virtually absent and the main consideration is the prevention of browning reactions and the development of off-flavours. It has been considered that low temperatures of concentration are less vital for apple juices (10, 11) and in the present tests subjection to a higher temperature in volatile stripping appeared beneficial rather than otherwise. The advantage gained by the addition of volatiles was lost if the concentrates were allowed to undergo deterioration on storage for, as found in the early tests (2) and as noted by Nimmo and co-workers (12), the development of off-flavours masks apple aroma. These workers similarly found apple concentrates to remain stable at −18°C. and to show marked deterioration at room temperature. Storage conditions appear to be less stringent for apple than for blackcurrant concentrates, for the changes occurring at 0–2°C. in the present tests were less marked in apple concentrates of high specific gravity than they were in the blackcurrant products, although these were concentrated to a lower degree. The use of very low temperature storage for apple concentrates would, for many purposes, be uneconomic, but the present results emphasise the advantages of storage at temperatures in the neighbourhood of 0°C. The use of small amounts of sulphur dioxide may, under such conditions, be found beneficial.

Summary.

A study has been made of the effects of concentration treatments and of storage temperatures upon the quality and stability of blackcurrant and apple juice concentrates.

Blackcurrant concentrates of high quality can be prepared if excessive heating is avoided and if the volatile components of the juice are retained. The quality of the concentrates deteriorates at temperatures of storage higher than 0°C. owing to adverse changes in colour and flavour and to losses of

ascorbic acid. The changes are slight at —23°C., rapid at 18°C., and are delayed to some extent by the addition of sulphur dioxide.

The effects of heat treatments during concentration are less marked in apple juice concentrates than in the blackcurrant products. Storage of apple concentrates at temperatures above 0°C. leads to adverse changes in colour and flavour ; at —23°C. the changes are slight.

Acknowledgments.

The authors are indebted to Messrs. Kestner Evaporator and Engineering Co. Ltd. for offering facilities for low temperature concentration, and to Dr. R. Gane of the Low Temperature Research Station, Cambridge, for undertaking the freeze concentration of blackcurrant juice.

They also wish to acknowledge the assistance of Mr. P. E. W. Rodgers in the experimental work.

REFERENCES.

(1) *Recent advances in fruit juice production.* Tech. Comm. No. 21, Commonwealth Bureau of Horticulture and Plantation Crops (1950), 91.
(2) Charley, V. L. S., Hopkins, D. P. and Pollard, A. (1941). *Ann. Rep. Long Ashton Res. Sta.* (1940), 97.
(3) Milleville, H. P. and Eskew, R. K. (1944). *Fruit Prod. J.*, **24,** 48.
(4) Pollard, A., Kieser, M. E. and Bryan, J. D. (1946). *Chem. Ind.*, **45,** 402.
(5) Pederson, C. S., Beattie, H. G. and Stotz, E. H. (1947). *N.Y. Agric. Expt. Sta., Geneva,* Bull. No. 728.
(6) Lee, F. A., Robinson, W. B., Hening, J. C. and Pederson, C. S. (1950). *Ibid.*, Bull. No. 743.
(7) Huelin, F. E. (1953). *Food Res.*, **18,** 633.
(8) Heiss, R. (1953). *Fruits d'Outre Mer*, **8,** 165.
(9) Curl, A. L. (1947). *Canner*, **105,** No. 13, 14. (via. *Chem. Abstr.*, 1948, **42,** 695).
(10) Kaufman, V. F., Nimmo, C. C. and Walker, L. H. (1950). *U.S. Bur. Agric. Ind. Chem.*, AIC, 293.
(11) Walker, L. H., Patterson, D. C. and Seamans, V. S. (1954). *Food Technology*, **8,** 108.
(12) Nimmo, C. C., Walker, L. H. and Seamans, V. S. (1952). *Food Technology*, **6,** 31.

A COMPARISON OF SOME VARIETIES OF FRUIT PRESERVED BY BOTTLING AND BY FREEZING. PROGRESS REPORT IV.

By ALICE CRANG and MARGARET STURDY.

During 1953 the preserving qualities of twenty-four varieties of plums grown at Long Ashton were compared after storage by bottling and by deep freezing. The qualities of ten varieties of raspberries, grown at the National Agricultural Advisory Service Sub-Centre, Starcross, Devon, were also compared fresh and after processing.

Preserving Methods.

The plums were held for one or two days at room temperature until they were at the firm-ripe stage. Representative samples were then bottled or frozen, using the processes detailed in Table I.

TABLE I.

PRESERVING AND THAWING METHODS.

Fruit	Preserving Method	Syrup used	Thawing Method
A. Plums : all varieties ; whole ..	Bottled*	Yes	—
B. „ gage varieties ; whole ..	Frozen	Yes	17 hours at 36°–40°F. then cooked until tender.
C. „ „ „ „ ..	„	No	17 hours at 36°–40°F.
D. „ gage varieties ; halved ..	„	Yes	Cooked without previous thawing.
E. „ other than gages ; whole ..	„	Yes	17 hours at 36°–40°F. and 2 hours at about 60°F.
F. „ other than gages	„	Yes	Cooked without previous thawing.
G. Raspberries ; whole	Bottled*	Yes	—
H. „ „	Fresh	No	—
I. „ „	Frozen	Yes	17 hours at 36°–40°F. and 2 hours at about 60°F.

*See " ABC of Preserving " 2nd Edn., published by H.M.S.O., for processing details using the Quick Water-bath method.

The raspberries were picked when ripe and three representative samples of each variety taken : the first was bottled the same afternoon using jars with glass lids ; the second was sealed in " Polythene " bags, held in insulated boxes containing solid carbon dioxide during transport and transferred that evening to a deep-freeze cabinet ; the third sample was held in cooled containers during transport and judged the next day for fresh fruit quality.

The proportions of fruit to syrup were as follows : plums 11½ oz. fruit to 6 fl.oz. of 30° Brix syrup ; raspberries 12 oz. fruit to 5 fl.oz. of 40° Brix syrup.

The preserving and thawing methods used are given below. The method of packaging and storing in the deep-freeze cabinet was similar to that used in previous years (1, 2).

Judging Methods.

The plum varieties were grouped into gages, yellow, red and purple plums for judging after 3 months' storage, bottled and frozen samples being tasted separately.

The fresh raspberries were compared on the day after picking and the preserved fruit after 4 months' storage, all the frozen raspberries being judged in the morning and the bottled fruit in the afternoon of the same day.

Ten members of a tasting panel judged the raspberries and the bottled plums, and seven or more members judged the frozen plums.

As in previous years the fruit was put into identical glass bowls and numbered with a code number. The same system of scoring was used (1), but the marks given for size and sugar/acid balance are not quoted ; comment has been made when these were of particular interest. The allocation of marks for colour, texture and flavour was such that 8·5 or more denoted outstanding quality ; 8·4 to 7·5 good ; 7·4 to 6·5 fairly good to fair ; 6·4 to 5·0 poor to very poor ; below 5·0 unacceptable.

It is realized that individual preferences give more weight to one quality than another when assessing the general acceptability of fruits, and no attempt is made in this report to express the figures as a total for comparisons of the varieties or methods.

Results.

Plums.

The mean marks awarded for colour, texture and flavour of the bottled gages are given in Table II ; those for other varieties of bottled and frozen plums are given in Table III.

Preserving Methods.

The differences in quality of the bottled gages were not outstanding, most being considered of good or fairly good colour ; the texture of all varieties was fairly good, with a tendency for the skins to be tough ; the flavour varied from good to fair.

None of the methods of thawing the frozen gages proved satisfactory, although slow thawing had previously been found suitable for other kinds of fruit. The whole gages in syrup, thawed slowly at 36°–40°F. before cooking until tender (Method B, Table I), became brown and all were rated as unacceptable, the mean figure for colour being 3·5. All were marked below the corresponding bottled fruit, with the means for flavour ranging from 7·1 to 4·6. The whole gages frozen without syrup (Method C) were so discoloured after slow thawing at 36°–40°F. that they were all considered unacceptable and were not marked. The halved gages in syrup (Method D), cooked without preliminary thawing, were poor or unacceptable in colour and flavour, ranging

from 6·1 to 4·0 in colour, and 7·1 to 4·7 in flavour. There was little difference in texture between samples, all being rather broken, with mean scores between 7·7 and 6·3. From these results it was apparent that the freezing and thawing methods used in these tests were not satisfactory for the gage varieties of plums.

TABLE II.

PLUMS : GAGE VARIETIES.

Bottled Fruit.

Variety	Colour	Texture	Flavour
Bryanston Gage	7·9	7·6	7·9
Cambridge Gage	7·3	7·5	7·7
Count Althann's Gage	7·1	7·0	6·5
Denniston's Superb	6·8	7·0	7·1
Early Transparent Gage	7·3	7·4	7·7
Jefferson's Gage	7·9	7·0	7·5
Laxton's Gage	7·2	7·1	6·6
Oullin's Gage..	8·8	7·5	7·7
Mean of all varieties	7·5	7·3	7·3

In the plum varieties other than gages, the colour of the bottled fruit was preferred to that of the raw or cooked frozen fruit for all varieties except Belle de Louvain, Monarch and President, and the flavour of the bottled plums was preferred for all except Belle de Louvain, Purple Pershore and Victoria. The skins tended to be slightly tough in the bottled and in the cooked frozen fruit ; the toughness was more pronounced in the uncooked frozen fruit. The damsons and the Frome Cross and Purple Pershore plums were considered to be too sour, especially the frozen whole fruit. The quality of the frozen plums was very disappointing in view of the 1952 trials in which mean scores for the colour and flavour of the raw plums, frozen whole in syrup, were 8·6 and 7·7 respectively (2). In the present series of tests the plums cooked without thawing were preferred to the thawed whole plums mainly on account of the browning developed by the thawed fruit ; this affected flavour as well as appearance.

Varieties.

Oullin's Gage, Bryanston Gage and *Pershore Yellow Egg* are the only three varieties that were rated good for all three qualities under consideration when preserved by bottling : none of them was satisfactory when preserved by freezing.

Thames Cross looked very attractive when bottled. but the skins were tough ; the flesh was badly discoloured in both the frozen samples.

TABLE III.

PLUMS : VARIETIES OTHER THAN GAGES.

Variety	Bottled			Frozen Whole, Raw			Frozen Halves, Cooked		
	Colour	Texture	Flavour	Colour	Texture	Flavour	Colour	Texture	Flavour
Allgrove's Superb	6·6	6·1	7·2	3·3	6·6	5·7	5·1	6·4	6·1
Belle de Louvain	6·3	7·1	6·3	5·6	6·1	6·0	6·4	7·6	6·4
Czar	6·2	7·3	8·1	—	—	—	—	—	—
Frome Cross	7·6	7·1	6·9	6·9	7·0	5·4	6·4	6·9	6·7
Giant Prune	7·8	6·8	7·5	6·7	6·3	5·6	7·0	7·6	6·4
Marjorie's Seedling	6·5	6·6	7·4	6·3	6·1	6·6	5·6	6·9	7·0
Monarch	5·6	7·4	7·8	6·9	6·4	6·3	6·6	7·3	6·6
Pershore (Yellow Egg) ..	8·1	7·5	7·7	5·9	6·7	6·6	6·1	6·3	6·3
President	6·4	6·8	7·5	7·6	6·3	6·6	6·6	7·6	7·4
Purple Pershore	7·4	7·3	6·4	5·9	6·9	5·9	6·7	7·4	7·0
Shropshire Prune Damson ..	8·3	8·0	7·4	7·0	6·7	5·6	—	—	—
Teme Cross	7·4	7·2	7·5	7·1	6·0	6·7	5·7	6·3	7·1
Thames Cross	9·0	6·2	7·2	5·6	5·6	5·9	7·3	6·9	5·9
Victoria	7·4	7·7	6·8	7·3	6·9	6·9	7·1	7·3	7·0
Warwickshire Drooper ..	8·1	7·4	6·5	5·4	6·4	5·3	6·6	7·0	5·0
Long Ashton Seedling NA.10 ..	7·0	7·3	7·0	5·3	6·3	6·4	5·7	7·0	6·7
Mean of all varieties	7·2	7·1	7·2	6·2	6·4	6·1	6·4	7·0	6·5

Shropshire Prune Damson needed a higher proportion of sugar than was given to the bottled fruit but it preserved well by this method. It should have been cooked after freezing before tasting.

Victoria was considered one of the best of the frozen fruits, being rated fair in all three qualities both as raw fruit and when cooked after freezing.

The President and *Purple Pershore* were rated as fair quality when cooked after freezing but the texture of the first and the colour and flavour of the second were poor when served raw after freezing.

Raspberries.

The results of tasting the fresh fruit and that stored for four months by bottling or freezing are given in Table IV.

Preserving Methods.

The chief difference in quality between the bottled and the frozen raspberries was in the colour, which was well retained in the frozen fruit, whereas in the bottled fruit most varieties looked too pale, as the colour had been extracted by the syrup. There was some breakdown of the fruit when frozen, and more in the bottled samples.

The average mark for flavour was almost identical in the fresh, bottled and frozen fruit. The proportion of fruit to syrup was considered satisfactory.

TABLE IV.

RASPBERRIES.

Variety	Fresh			Bottled			Frozen		
	Colour	Texture	Flavour	Colour	Texture	Flavour	Colour	Texture	Flavour
Landmark	6·2	6·9	6·7	4·4	5·0	5·8	5·8	6·1	6·0
Lloyd George ..	7·7	7·9	6·7	8·0	6·8	6·7	8·0	7·4	7·0
Malling Enterprise..	8·1	8·5	6·7	5·7	6·5	6·4	8·2	7·7	7·1
Malling Exploit ..	6·9	6·4	4·7	5·0	5·0	5·9	7·2	7·2	5·8
Malling Jewel ..	8·0	8·0	5·8	4·7	6·8	6·5	7·6	7·3	6·3
Malling Promise ..	6·6	7·2	5·2	6·4	6·8	6·2	7·0	6·6	6·2
Malling V	8·2	8·6	7·4	5·0	5·9	5·8	6·6	6·9	6·0
Malling W	7·8	6·6	5·9	5·5	6·6	6·2	7·5	6·5	5·7
Newburgh	6·3	7·6	6·4	4·6	5·4	6·2	6·8	5·5	5·6
Norfolk Giant ..	8·0	6·9	7·2	6·2	6·7	7·7	8·6	7·8	8·0
Mean of all varieties	7·4	7·5	6·3	5·6	6·2	6·3	7·3	6·9	6·4

Varieties.

Malling V was considered the best variety as fresh fruit : it did not preserve well either by bottling or freezing.

Lloyd George was consistently good for colour, and the fruit remained reasonably whole, but the flavour was considered only fair in both methods of preserving.

Norfolk Giant was considered the best of the series when frozen ; the bottled fruit was the only one to be rated good in flavour ; its colour was poor.

The appearance of *Malling Enterprise* and *Malling Jewel* was good in both fresh and frozen fruit but the flavour of the first was considered only fair, and that of the second poor. Both varieties were poor when bottled.

Malling W had good colour in the fresh and frozen fruit ; the texture was only fair and the flavour poor in both methods of preserving.

All the other varieties were considered to be only fair or poor in colour, texture and flavour in both methods tested.

Malling Enterprise, *Malling Jewel* and *Malling V* were in very good condition after transport as fresh fruit.

Discussion.

The results of freezing different varieties of plums in 1952 were so encouraging that an extension of this work was carried out in 1953. These results have, however, proved very disappointing. As the proportions of fruit to syrup, the containers and the temperatures of freezing were the same for the two series, the differences in results can be attributed only to variations in the time taken between preparation of the fruit and freezing and/or to the different thawing treatments. There was no intentional variation in the treatment of the whole fruit before freezing, but it seems as if some discoloration of the halved plums occurred before they were frozen, and that precautions will have to be taken to prevent this. In the 1952 trials, the fruit was held overnight just above freezing point before thawing at room temperature, whereas in these tests the overnight temperature was 36°–40°F. for the whole fruit. Although the fruit still required a further two hours at room temperature before it was thawed sufficiently for tasting, the slightly higher thawing temperature may have caused the differences in results. The halved fruit, cooked without any thawing, certainly showed less discoloration than the whole fruit, but was inferior to that preserved by bottling.

The results emphasize that any fruit liable to discolour in the air needs very careful treatment if this is to be prevented when it is frozen : gage varieties are especially susceptible to this trouble.

The four varieties of plums judged to be the best for bottling were Pershore (Yellow Egg), Shropshire Prune Damson, Oullin's Gage and Bryanston Gage. Those varieties previously tested (2) showed only slight differences in bottling qualities in the two seasons' trials.

This is the first year that extensive raspberry trials have been carried out and the results have proved interesting. Malling V, a variety said to be a poor cropper in Kent, has grown well in the moister climate of Devon and was judged the best of the fresh fruits, though it did not preserve well. Exploit, which has given phenomenal crops, had the poorest flavour of the fresh fruits and did not preserve well. Of the frozen fruits, Norfolk Giant had the best colour and flavour, followed by Malling Enterprise and Lloyd George. Of the bottled fruits Norfolk Giant was again considered to have the best flavour whereas Lloyd George had the best colour. The flavour of all the newer varieties was considered weak.

Summary.

The results of tasting tests on 24 varieties of plums, preserved by bottling and by freezing, and on 10 varieties of raspberries, judged as fresh fruit as well as after bottling and freezing, are given. The frozen raspberries were superior in colour and texture to the bottled fruit, but this order, with three exceptions, was reversed in the plums. Discolouration of the frozen plums was severe and this affected the flavour.

Acknowledgments.

Our thanks are due to Miss Margaret Hooper for processing the fruits, to all members of the tasting panel, and to Mr. W. C. Ibbett for arranging the collection of the raspberries and giving facilities for preserving the fruit on the day of picking.

REFERENCES.

(1) Crang, A., Kendall, L. and Sturdy, M. (1951). *Ann. Rep. Long Ashton Res. Sta.*, 1950, 197-207.

(2) Crang, A. and Sturdy, M. (1953). *Ibid.*, 1952, 177-185.

NOTES ON DOMESTIC MEAT AND POULTRY PRESERVATION.

By ALICE CRANG.

Reference has been made in the Introduction to the reasons for undertaking research into domestic methods of preserving meat and poultry. Two main aspects of the work now being studied are :—

(a) conditions necessary for safe bottling or canning, and

(b) requirements for successful deep-freezing.

(a) Bottling and Canning.

The conditions necessary for safe bottling and canning of meat and poultry in the home have been prescribed in the U.S.D.A. leaflet " Home Canning of Meat," based on research work reported in U.S.D.A. Technical Bulletin 930 (1). These all require that the bottles or cans should be processed for varying lengths of time at 10 lb. per sq. in. steam pressure (approx. 240°F.), depending on the size of jar and the nature of the contents. There are, however, considerable differences in the equipment used for preserving in America and in this country ; for instance, glass jars have been found to vary considerably both in their thickness and diameter, and trials with some of them indicate that longer processing may be necessary than that recommended for jars of similar capacity in the American publications. Variations in the temperature maintained in cookers registering 10 lb. per sq. inch are also being investigated, since any recommended processing time must allow for the greatest fall below 240°F. likely to occur as a result of low atmospheric pressure or variations in the controls of the different pressure cookers.

Two methods are being used for testing the adequacy of a process : the food is inoculated with a test organism to see whether it survives the treatment, and the " lethal value " is calculated from the temperatures plotted during the process. The test organism is a sporing culture of Cameron's Putrefactive Anaerobe No. 3679. This organism is non-toxic and the spores have a greater heat-resistance than the pathogenic organisms found in food ; it is therefore very suitable for tests and is widely used by the canning industry.

The spores of the most heat-resistant pathogenic organism known to affect food are destroyed in a rapidly decreasing time as the temperature approaches 250°F. It is possible to express the effectiveness of temperatures below 250°F. as fractions of the time required to destroy the organism by instantaneous heating at 250°, and the sum of these values for a given process is termed the " lethal value " of the process. The lethal value for each container and type of pack is being calculated from the temperatures recorded at two-minute intervals during the period of processing at which the contents are above 190°F., and at least 5 replicates of each process are being made. These results are being compared closely with those found by the American workers (1).

(b) Deep Freezing.

The methods of deep-freezing meat and poultry being examined are also based on American recommendations (2) (3), but modified to suit the methods of preparation and cooking generally required in this country. Most deep-freeze cabinets for domestic use have a temperature range of –20° to 0°F. At these temperatures there is considerable evaporation unless adequate protective covering is used, and there may be oxidative changes causing rancidity. These two factors are being considered when testing the suitability of wrapping material for the meat and poultry during freezing. Pork is being used to test the length of storage before the onset of rancidity, since pork fat is considered to be more susceptible than most other kinds of fat.

Chicken and pork are being used for the initial freezing tests, since information on these seem to be most urgently required by domestic preservers. The length of time and method of treatment between killing and freezing are also being considered in relation to the quality of the frozen product.

REFERENCES.

(1) Toepfer, E. W., Reynolds, H., Gilpin, G. L. and Taube, K. (1946). *U.S. Dept. Agric. Tech. Bull.* No. 930.

(2) Tressler, D. K. and Evers, C. F. (1947). *The Freezing Preservation of Foods.* Avi Publishing Co., New York.

(3) Masterman, N. K. and Lee, F. A. (1950). *The Home Freezing of Farm Products.* Cornell Extension Bulletin No. 611.

METEOROLOGICAL RECORDS, 1953

Month	Air Temperature (°F.)							Rainfall (″)			Sunshine (hours)			Soil Temperature at 09.00 G.M.T.		
	Means		Means of A & B	Dif. from average	Max.	Min.	No. of ground frosts	Total	Dif. from average	Most in a day	Total	Dif. from normal	Daily average	4″	8″	24″
	A Max.	B Min.														
January	43·3	32·4	37·9	—2·7	52	22	21	0·74	—2·63	0·35	40·6	— 7·3	1·31	36·8	37·8	40·3
February ..	45·7	33·9	39·8	—0·9	60	26	16	1·74	—0·84	0·52	64·1	— 3·0	2·29	37·5	38·4	40·4
March	51·0	33·8	42·4	—1·5	68	25	23	0·93	—1.40	0·47	128·9	+ 6·4	4·16	39·8	40·1	42·3
April	54·5	38·4	46·5	—1·3	68	30	13	4·07	+1·74	0·89	190·7	+31·3	6·36	45·4	45·1	46·9
May	64·8	46·4	55·6	+2·5	81	32	5	1·91	—0·68	0·65	212·5	+17·2	6·85	55·5	54·3	54·1
June	66·9	50·1	58·5	+ 0·1	79	41	0	2·15	+0·04	0·64	157·3	— 55·4	5·24	57·9	58·6	58·9
July	67·7	53·6	60·6	—1·1	76	47	0	4·12	+ 0·96	0·98	229·7	+33·6	7·41	62·1	61·3	62·9
August	69·9	53·5	61·7	+0·6	82	45	0	5·36	+1·71	1·86	206·7	+21·0	6·67	62·4	61·7	63·6
September ..	64·7	50·1	57·4	+0·1	73	42	0	3·48	+0·33	0·99	139·9	— 1·5	4·66	57·1	57·6	61·2
October	58·0	42·8	50·4	—0·7	68	33	10	2·86	— 0·99	0·68	100·7	— 0·1	3·25	50·4	51·6	55·8
November ..	53·4	42·8	48·1	+ 3·4	59	33	9	2·05	—1·65	0·45	47·8	— 9·3	1·59	46·4	47·1	50·6
December ..	50·8	41·1	45·9	+4·5	60	31	11	0·99	— 2·58	0·30	41·1	— 5·3	1·33	45·2	46·0	49·3
Totals or Means ..			50·4	+0·3			108	30·40	—5·99		1560·0	+27·6	4·27	49·7	50·0	52·2

G. E. Clothier.

THE MOLYBDENUM REQUIREMENTS OF TOMATO PLANTS GIVEN DIFFERENT TYPES OF NITROGEN SUPPLY IN SAND CULTURE.

By E. J. HEWITT and C. C. McCREADY,
A.R.C. Unit of Plant Nutrition (Micro-nutrients).

Previous experiments with cauliflower (1, 2) showed that this plant required molybdenum for normal growth when nitrogen was supplied as nitrite, ammonium salts, urea or glutamic acid, and indicated that molybdenum fulfilled some role other than that known in nitrate reduction. As the whiptail symptoms used as one of the criteria to show a need for molybdenum are apparently confined to the brassica genus it was thought necessary to extend the observations to some other type of plant. Tomato was chosen because its response to molybdenum deficiency under nitrate nutrition is well known and it is a plant widely used for nutritional investigations.

Experimental.

Methods. Plants were grown in sand cultures using the general methods already described (2, 4). Nitrogen was given at 12 mM/L in the following forms : nitrate, nitrite, ammonium sulphate, ammonium nitrate, ammonium nitrite, urea or glutamic acid. Purified calcium carbonate (2) was mixed in the purified sand (4) and all nutrient reagents were purified (4). Pyrex urns holding 3 plants in 7 kg. sand were used for the molybdenum deficiency treatments and bitumen-painted clay pots holding 4 plants in 9·5 kg. sand were used as containers for the normal molybdenum treatments.

One extra pair of treatments with nitrate, but omitting the calcium carbonate, was included to test whether the calcium carbonate affected the production of molybdenum deficiency.

There were 6 replicates in each treatment distributed between 6 randomised blocks. The + and — Mo treatments were segregated in split plots to avoid contamination. In two blocks the split plots were separated by greater distances than the rest but the statistical analysis was used without regard to this defect. There was no evidence of abnormality arising from the layout. Block effects were non-significant and the significance of results was high.

Visual symptoms were recorded and percentage dry matter, total dry weights, chlorophyll, ascorbic and dehydroascorbic acids and nitrate content were determined ; they are given in Table I.

Results.

Visual symptoms. All plants given molybdenum grew normally and were devoid of any visual symptoms. In the deficiency series two groups of symptoms were observed. In the plants given nitrate or ammonium nitrate severe typical symptoms of molybdenum deficiency, as previously recorded (3, 5, 7) were observed. A few plants given ammonium sulphate or ammonium nitrite showed occasional mild symptoms suggestive of those in the nitrate groups.

TABLE I.

EFFECTS OF MOLYBDENUM SUPPLY ON YIELDS (G. DRY WT.) AND CHLOROPHYLL CONTENT (MG./100 G. FRESH WT.), ASCORBIC AND DEHYDROASCORBIC ACIDS (MG./100 G. FRESH WT.) AND NITRATE CONTENT (PERCENTAGE IN DRY WT.) OF TOMATO PLANTS GROWN WITH DIFFERENT SOURCES OF NITROGEN. (MEANS OF 6 BLOCKS).

Nitrogen source	Yield		Per cent. Dry matter		Chlorophyll		Ascorbic acid		Dehydroascorbic acid		Nitrate	
	—Mo	+Mo	—Mo	+Mo	—Mo	+Mo	—Mo	+Mo	—Mo	+Mo	—Mo	+Mo
Nitrate	12·78	23·82	11·07	16·87	11·06	18·05	48·15	89·01	50·96	105·44	5·18	1·06
Nitrate + $CaCO_3$	9·57	25·03	8·41	16·89	8·16	15·79	27·35	82·64	31·15	71·27	7·29	0·87
Nitrite + $CaCO_3$	9·50	18·71	13·19	15·84	17·94	19·94	67·39	79·41	74·54	90·41	1·11	0·65
Ammonium sulphate + $CaCO_3$	15·90	19·38	13·57	15·92	21·56	17·44	63·20	87·94	62·76	95·60	1·04	0·58
Ammonium nitrate + $CaCO_3$	13·65	23·61	10·89	17·66	12·86	16·96	43·73	86·82	53·71	72·79	4·75	1·09
Ammonium nitrite + $CaCO_3$	13·93	21·94	13·70	17·77	17·88	15·88	63·60	86·32	65·41	99·39	1·60	0·88
Urea + $CaCO_3$	12·27	27·63	14·53	14·98	16·85	18·66	68·14	79·81	74·27	90·82	0·85	0·92
Glutamic acid + $CaCO_3$	6·76	15·01	16·78	16·51	14·54	16·57	67·87	85·94	76·36	91·07	0·67	0·83
L.S.D. Mo effect (horizontal) P = ·05	3·27		2·00		2·72		15·40		25·09		0·899	
P = ·01	4·50		2·65		3·78		22·03		36·35		1·223	
P = ·001	6·32		3·84		5·37		32·76		55·19		1·682	
L.S.D. N effect (vertical) P = ·05	2·98		1·84		2·41		11·84		17·80		0·861	
P = ·01	3·95		2·95		3·20		15·69		23·59		1·141	
P = ·001	5·13		4·06		4·15		20·36		30·62		1·481	

The second group of symptoms comprised two effects. These were both confined entirely to molybdenum deficient plants given non-nitrate sources of nitrogen and occurred sporadically. One symptom was the development of small, very dark brown areas in the margins of older leaves; they were possibly necrotic but this is not certain. They were similar to previously unidentified symptoms produced in an experiment (6) in which the possible essentiality of other micronutrients was being investigated: plants given glutamic acid showed the most marked incidence. The other symptom occurred in mid-stem regions. It comprised wilting and rapid withering of leaf tips or whole leaflets which remained green or grey-green when dry and were free from the characteristic yellow-green mottling associated with the nitrate treatments. Plants given urea or nitrite were most affected.

Plants given glutamic acid in the molybdenum deficient treatment were somewhat pale and suggestive of mild nitrogen deficiency.

Percentage dry matter. The percentage dry matter in leaves was markedly reduced by molybdenum deficiency in the presence of nitrate or ammonium nitrate ($P < \cdot001$). There were smaller decreases with nitrite ($P < \cdot01$) ammonium sulphate ($P < \cdot05$) and ammonium nitrite ($P < \cdot001$), but no changes with urea or glutamic acid. Values were more uniform in the presence of molybdenum and N × Mo interaction was highly significant ($P < \cdot001$).

Yields. Growth was reduced by molybdenum deficiency with all nitrogen sources. The depression was largest with nitrate and ammonium nitrate. Results were highly significant ($P < \cdot001$), for all treatments except ammonium sulphate where lower significance ($P < \cdot05$) was obtained. The N × Mo interaction was highly significant ($P < \cdot001$).

Chlorophyll. Total chlorophyll content was markedly decreased *only* in the presence of nitrate or ammonium nitrate ($P < \cdot001$—$\cdot01$). There were slight decreases with nitrite, urea or glutamic acid, and increases with ammonium nitrite or ammonium sulphate. The last was significant ($P < \cdot01$).

The N × Mo interaction, due mainly to nitrate and ammonium nitrate *versus* the remainder, was highly significant ($P < \cdot001$).

Ascorbic acid and dehydroascorbic acid. Ascorbic acid (AA) was decreased by molybdenum deficiency with all nitrogen sources. The overall effect was highly significant ($P < \cdot01$): individual effects varied with nitrogen sources. The decrease with nitrate was also highly significant ($P < \cdot001$). Decreases with the other nitrogen sources were smaller but achieved the following significant levels: ammonium sulphate, ammonium nitrate ($P < \cdot01$): glutamic acid ($P < \cdot05$); nitrite, urea not significant. The overall effect for non-nitrate sources of nitrogen was also highly significant ($P < \cdot01$).

The N × Mo interaction due to the difference between nitrate or ammonium nitrate and the rest was also highly significant ($P < \cdot001$).

Dehydroascorbic acid (DHA) showed similar variations but at slightly lower levels of significance; the N × Mo interaction was significant ($P < \cdot01$).

The proportion of DHA to AA was relatively constant and was much greater than that in cauliflower, being about 1·1 : 1·0 as compared with about 0·1–0·2 : 1·0. There was no effect of molybdenum on this ratio.

Nitrate content. Marked nitrate accumulation occurred with molybdenum deficiency in the presence of nitrate or ammonium nitrate ($P < \cdot001$). There was a detectable amount of nitrate in all plants and slight but not significant

accumulation also occurred in the presence of ammonium sulphate or ammonium nitrite in the molybdenum deficient plants. The N × Mo interaction was highly significant ($P < \cdot001$).

Discussion.

The results justify the conclusion that molybdenum is required by tomato for growth and ascorbic acid production in the presence of non-nitrate sources of nitrogen as well as of nitrate. Molybdenum appears to be of little or no importance in chlorophyll production provided a readily assimilable nitrogen, source is available. The presence of nitrate, however, appears to cause loss of chlorophyll when molybdenum is deficient in spite of the presence of assimilable nitrogen as the ammonium ion. This confirms the conclusion reached in the cauliflower experiment (2). The absence or masking of all but occasional visual symptoms under deficiency conditions in the absence of nitrate is of great interest. It suggests that the role of molybdenum, apart from that in nitrate reduction, is such that under deficiency conditions growth as a whole may be depressed without the marked production of the unbalanced conditions that in other instances of mineral deficiencies presumably lead to the production of typical visual symptoms. The visual symptoms produced here and in other experiments (3, 5, 7) with nitrate nitrogen appear to bear some specific relation to problems of nitrate injury as well as non-assimilation since they occur also with ammonium nitrate in tomato, and with this source or with nitrate plus nitrite in cauliflower (2).

The other point of importance disclosed is shown by the highly significant molybdenum × nitrogen interactions. These suggest that, although molybdenum is required by the tomato plant grown with non-nitrate sources of nitrogen, the quantitative molybdenum requirements, or the depressive effects of its deficiency under these conditions, may be significantly less than in the presence of nitrate. The fact that plants given ammonium nitrate behave more nearly like those given nitrate alone would suggest that lack of assimilable nitrogen is not the only reason for the difference in requirements. Three effects would thus appear to require consideration, namely, nitrate reduction (or assimilation), nitrate injury, and some other role independent of the source of nitrogen.

The possibility that nitrate injury may be one factor contributing to the apparent independent requirement cannot be excluded at present. The presence of nitrate in plants in all treatments irrespective of molybdenum supply and the lack of any relative accumulation in some deficiency treatments, suggest that slight nitrification, or even nitrate production, which may have occurred within the plant, does not account for the main effects observed here. The effects observed in cauliflower in similar experiments, in which much lower concentrations of nitrate were used, are consistent with this view.

Acknowledgments.

We wish to thank Mr. G. M. Clark for the statistical analysis of the results and Miss R. A. Paget for analytical assistance.

REFERENCES.

(1) Agarwala, S. C. (1952). Relation of nitrogen supply to the molybdenum requirement of cauliflower grown in sand culture. *Nature*, **169,** 1099.

(2) Agarwala, S. C. and Hewitt, E. J. (1953). The effects of some different nitrogen sources on the molybdenum requirements of cauliflower plants grown in sand culture. *Ann. Rep. Long Ashton Res. Sta.*, 1952, 195.

(3) Arnon, D. I. and Stout, P. R. (1939). Molybdenum as an essential element for higher plants. *Plant Physiol.*, **14,** 599.

(4) Hewitt, E. J. (1952). *Sand and water culture methods used in the study of plant nutrition. Tech. Commun. Bur. Hort. East Malling*, No. 22.

(5) Hewitt, E. J. and Jones, E. W. (1947). The production of molybdenum deficiency in plants in sand culture with special reference to tomato and brassica crops. *J. Pomol.*, **23,** 254.

(6) Hewitt, E. J. and Bolle-Jones, E. W. (1952). Investigations on possible micronutrient elements for higher plants : I. Experiments with cobalt, nickel and gallium in sand culture. *Ann. Rep. Long Ashton Res. Sta.*, 1951, 62.

(7) Hewitt, E. J. and Bolle-Jones, E. W. (1952). Molybdenum as a plant nutrient : II. The effects of molybdenum deficiency on some horticultural and agricultural crop plants in sand culture. *J. hort. Sci.*, **27,** 257.

PUBLICATIONS, 1953

(Including those of the A.R.C. Unit of Plant Nutrition).

Agarwala, S. C.
Relation of nitrogen supply to the molybdenum requirement of cauliflower grown in sand culture. *Nature*, **169,** 1099.

Barker, B. T. P.
Long Ashton Research Station, 1903–1953. *J. hort. Sci.*, **28,** 149–151.

Barker, B. T. P.
Cider and cider-making fifty years ago. *Science & Fruit*, 29–44.

Barker, B. T. P. and Burroughs, L. F.
Cider apple varieties then and now : a survey of vintage-quality trials. *Science & Fruit*, 45–55.

Beech, F. W.
Where cider gets its flavour. *Grower*, **38,** 342–343.

Beech, F. W. and Carr, J. G.
Disorders of cider. *Science & Fruit*, 68–77.

Bennett, S. H. and Thomas, W. D. E.
Experiments on the absorption and fate of a systemic insecticide, bis (bisdimethylamino) phosphonous anhydride, in plants. *Proc. Isotope Technique Conf., Oxford*, **1,** 439–445.

Bolle-Jones, E. W.
A study of the inter-relationships of iron and potassium in the potato plant. *Int. Soc. Soil Sci., Dublin*, 1952, **2,** 186–192.

Bolle-Jones, E. W. and Notton, B. A.
The relative proportions of the chloroplast pigments as influenced by different levels of iron and potassium supply. *Plant & Soil*, **5,** 87–100.

Bould, C.
Magnesium deficiency in apple trees. *Grower*, **40,** 1041–1044.

Bould, C.
Foliage sprays for correcting nutrient deficiencies of fruit trees. *R.H.S. Fruit Yr. Bk.*, **7,** 54–58.

Bould, C., Hobbis, E. W., Kearns, H. G. H. and Marsh, R. W.
Some aspects of blackcurrant culture. *Science & Fruit*, 120–130.

Bould, C., Nicholas, D. J. D. and Thomas, W. D. E.
Radiation effects with phosphorus-32 in barley and tomato plants grown in soil. *Int. Soc. Soil Sci., Dublin*, 1952, **2,** 92–94.

Bould, C., Nicholas, D. J. D. and Thomas, W. D. E.
Radiation effects with radio-active phosphorus in barley and tomato grown in soil. *Plant & Soil*, **5,** 36–53.

Bould, C., Nicholas, D. J. D. and Tolhurst, J. A. H.
Copper and zinc deficiencies in soil and fruit trees in Britain. *Int. Soc. Soil Sci., Dublin*, 1952, **2,** 172–175.

Bould, C., Nicholas, D. J. D., Tolhurst, J. A. H. and Potter, J. M. S.
Zinc deficiency of fruit trees in Great Britain. *J. hort. Sci.*, **28,** 260–267.

Bould, C., Nicholas, D. J. D., Tolhurst, J. A. H. and Potter, J. M. S.
Copper deficiency of fruit trees in Great Britain. *J. hort Sci.*, **28,** 268–277.

Byrde, R. J. W., Crowdy, S. H. and Woodcock, D.
Studies in systemic fungicides : III. The activity of certain chlorine-substituted beta-naphthols and naphthyloxy-*n*-aliphatic carboxylic acids as systemic fungicides. *Ann. appl. Biol.*, **40,** 152–165.

Byrde, R. J. W., Croxall, H. E., Jenkins, J. E. E. and Marsh, R. W.
Spraying experiments against apple and pear scab at Long Ashton and in the West Midlands. Season 1951. *J. hort. Sci.*, **28,** 196–206.

Byrde, R. J. W. and Woodcock, D.
Fungicidal activity and chemical constitution : II. Compounds related to 2:3-dichloro-1:4-naphthaquinone. *Ann. appl. Biol.*, **40,** 675–687.

Crang, Alice.
Preserves for all Occasions. 4th edn. (enlarged) pp. 164. Penguin Books, Harmondsworth.

Crang, Alice.
Scientific aspects of domestic fruit and vegetable preservation. *Science & Fruit*, 277–289.

Crang, Alice.
The home preservation of fruit. *R.H.S. Fruit Yr. Bk.*, **7,** 75–86.

Crang, Alice and Sturdy, Margaret.
Bottled and canned fruit : studies of processing requirements and fuel consumption by domestic methods. *J. Sci. Food Agric.*, **4,** 449–459.

Crowdy, S. H.
Observations on the effect of growth-stimulating compounds on the healing of wounds in apple trees. *Ann. appl. Biol.*, **40,** 197–207.

Forster, W. A.
The determination of magnesium in plant material by means of ethylenediaminetetra-acetic acid. *Analyst*, **78,** 179–180.

Hewitt, E. J.
The use of sand cultures for the study of mineral disorders, particularly micronutrient deficiencies. *Int. Soc. Soil Sci., Dublin*, 1952, **2,** 240–242.

Hewitt, E. J.
The importance of molybdenum in the nutrition of horticultural crops. *Proc. XIII int. hort. Congr.*, 375–385.

Hewitt, E. J.
The importance of trace elements in crop nutrition. *Brit. agric. Bull.*, **6,** 222–229.

Hewitt, E. J.
Metal inter-relationships in plant nutrition : I. Effects of some metal toxicities on sugar-beet, tomato, oat, potato and marrowstem kale grown in sand culture. *J. exp. Bot.*, **4,** 59–64.

Hewitt, E. J.
The use of sand-culture methods for investigations on plant nutrition. *Science & Fruit*, 171–183.

Hewitt, E. J. and Bolle-Jones, E. W.
Studies in iron deficiency of crops : II. The inter-relationships of iron and potassium in the potato plant. *J. hort. Sci.*, **28,** 185–195.

Hobbis, E. W.
Fruit tree training and planting. *Worcs. agric. Chron.*, **21,** 97–113.

Hobbis, E. W.
Orchard renovation by top-grafting. *R.H.S. Fruit Yr. Bk.*, **7,** 47–49.

Hobbis, E. W.
Fruit growing in the West of England. *Grower, Ann. Fruit Supp.*, 1953, 5–9.

James, Patricia and Woodcock, D.
Synthesis of plant-growth regulators. Part III. Dichloro-beta-naphthyloxy-acetic acids. *J. chem. Soc.*, 1953, 2089–2093.

Kearns, H. G. H.
Important pests of apples, 1920–50. *Science & Fruit*, 213–225.

Kearns, H. G. H. and Morgan, N. G.
Equipment for spraying apples and pears. *Grower, Ann. Fruit Supp.*, 1953, 32–35.

Kearns, H. G. H. and Morgan, N. G.
Fifty years of fruit spraying methods and machinery. *Science & Fruit*, 265–276.

Kieser, Margaret, Pollard, A. and Williams, A. H.
The occurrence of leuco-anthocyanins in perry pears. *Chem. & Ind.*, 1953, 1260.

Luckwill, L. C.
The mechanism of fruit drop in the pome fruits and its control by synthetic growth substances. *Rep. XIII int. hort. Cong.*, **1,** 223–229.

Luckwill, L. C.
Studies on fruit development in relation to plant hormones : I. Hormone production by the developing apple seed in relation to fruit drop. *J. hort. Sci.*, **28,** 14–24.

Luckwill, L. C.
Studies on fruit development in relation to plant hormones : II. The effect of naphthalene acetic acid on fruit-set and fruit development in apples. *J. hort. Sci.*, **28,** 25–40.

Luckwill, L. C.
How N.A.A. thins apples. *Amer. Fruit Grower*, **73,** 14.

Luckwill, L. C.
Plant hormone research at Long Ashton. *Science & Fruit*, 110–119.

Luckwill, L. C. (with Swarbrick, T.).
The factors governing fruit bud formation. *Science & Fruit*, 99–109.

Marsh, R. W.
Methods of plant pest and disease assessment. *Nature*, **171,** 553–555.

Marsh, R. W.
Insecticides and colonial agricultural development. *Nature*, **171,** 824–826.

Marsh, R. W.
Apple and pear scab. *Science & Fruit*, 226–236.

Marsh, R. W.
Long Ashton Research Station Jubilee celebrations. *Nature*, **172,** 273–274.

Marsh, R. W.
Apple and pear scab from 1903 to 1953. *Grower, Ann. Fruit Supp.*, 1953, 32–35.

Marsh, R. W.
Presidential address : the past and the future of The Annals of Applied Biology. *Ann. appl. Biol.*, **40,** 435–448.

Martin, J. T.
Distribution of copper fungicide deposits on plant surfaces. *Nature*, **172,** 313–314.

Martin, J. T.
Insecticides and fungicides in fifty years of fruit culture. *Science & Fruit*, 236–245.

Martin, J. T.
The chemical standardisation of insecticides and fungicides. *Science & Fruit*, 246–255.

Miles, Peggy
An investigation into the effects of mineral deficiencies in the Easter Lily. *Lily Yearbk.*, **16,** 79–83.

Nicholas, D. J. D.
Chemical Tissue Tests for determining the Mineral Status of Plants in the Field. The Tintometer Ltd., Salisbury.

Nicholas, D. J. D.
The mineral nutrition of fungi, with special reference to *Aspergillus niger* and *Penicillium glaucum*. *Science & Fruit*, 184–204.

Nicholas, D. J. D., Nason, A. and McElroy, W. D.
Effect of molybdenum deficiency on nitrate reductase in cell-free extracts of *Neurospora* and *Aspergillus*. *Nature*, **172,** 24.

Nicholas, D. J. D. and Thomas, W. D. E.
Some effects of heavy metals on plants grown in soil culture : I. The effect of cobalt on fertiliser and soil phosphate uptakes and the iron and cobalt status of tomato. *Plant & Soil*, **5,** 67–80.

Phillips, J. D. and Pollard, A.
Degradation of sugars on ion-exchange columns of Amberlite IRA 400 (OH'). *Nature*, **171,** 41.

Plant, W.
An analysis of the acid soil complex by the use of indicator plants. *Plant & Soil*, **5,** 54–66.

Pollard, A.
Fêtes jubilaires à la station de recherches de Long Ashton. *Fruits et Dérivés*, **25,** 10–12.

Pollard, A.
Vineyards in England (chapter on Wine). Faber & Faber, London.

POLLARD, A.
What makes the flavour in an apple? *Grower*, **40,** 874.

POLLARD, A.
Factors affecting the quality of cider. *Science & Fruit*, 56–67.

POLLARD, A.
Selected yeasts in cider-making. *Bottler & Packer*, **27,** 125.

POLLARD, A. (with CHARLEY, V. L. S.)
Developments in fruit products. *Science & Fruit*, 78–98.

SPINKS, G. T.
Fruit breeding at Long Ashton. *Science & Fruit*, 162–170.

STURDY, MARGARET.
New methods of fruit bottling. *Women's Gas Fed. Monthly Leaflet*, ser. 26, No. 3.

THOMAS, W. D. E. (with GLYNNE JONES, W. D.)
Experiments on the possible contamination of nectar with schradan. *Ann. appl. Biol.*, **40,** 546–555.

WALLACE, T.
Long Ashton Research Station. *The Times agric. Review*, March 1953.

WALLACE, T.
Some effects of orchard factors on the quality and storage properties of apples. *Science & Fruit*, 140–161.

WALLACE, T.
Research at Long Ashton. *Agriculture*, **60,** 131–137.

WALLACE, T.
Long Ashton Research Station. *Farmer & Stockbreeder*, 21 July, 1953.

WALLACE, T.
Plant diagnostic methods. *Int. Soc. Soil Sci., Dublin*, 1952, **1,** 231–239.

WALLACE, T.
Mineral deficiencies of garden crops. *Country Life*, 24 Sep., 1953, 957–959

WALLACE, T.
Some aspects of the mineral nutrition of horticultural plants. *Rep. XIII int. hort. Congr.*, **1,** 127–136.

WALLACE, T.
The diagnosis of the mineral status of plants with special reference to deficiencies, excesses and interactions of nutrient elements. *Proc. spec. Conf. Agric. Australia*, 1949, 100–113.

WALLACE, T. and BARKER, B. T. P.
Long Ashton Research Station: its origin and development. *Science & Fruit*, 11–28.

WALLACE, T. and MARSH, R. W. (Editors).
Science & Fruit, pp. xiii + 308: University of Bristol, 1953.

WILLIAMS, A. H.
The application of chromatographic methods to the study of the biochemistry and nutrition of plants. *Science & Fruit*, 205–212.

WILLIAMS, A. H.
The tannin of apple juice and cider. *Chemistry & Industry*, 1953, 540–541.

WOODCOCK, D.
The insecticidal activity of DDT and related compounds. *Science & Fruit*, 256–264.

THE JOURNAL OF HORTICULTURAL SCIENCE

The *Journal of Horticultural Science*, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editors at East Malling Research Station, Maidstone, Kent.

The current volume XXIX (1954) contains twenty-eight papers, of which twelve have been contributed by Long Ashton and East Malling. The subjects discussed include propagation of raspberries; cultural treatment, manuring of and flower bud initiation in strawberries; stock/scion investigations, particularly the effect of the intermediate in compatibility studies and inarching; mineral deficiencies in bulbs and molybdenum as a plant nutrient; prevention of frost damage; fruit thinning; virus diseases of cherries, brown rot in apples and plums and damping off in tomatoes; the artificial induction of seed fertility in tree fruits generally and seed fertility in bananas; fruit storage and soil sterilisation.

The Journal is issued in quarterly parts and is published by Messrs. Headley Brothers, 109 Kingsway, London, W.C.2, to whom intending subscribers should apply. The subscription rates are 50 shillings per volume (rate for Canada and the U.S.A. $7.00) or 15 shillings for a single number.